A MANUAL

OF THE

GEOLOGY OF INDIA.

ECONOMIC GEOLOGY.

BY THE LATE

PROFESSOR V. BALL, C.B., LL.D., F.R.S.

SECOND EDITION REVISED IN PARTS.

PART I.—CORUNDUM.

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PREFACE.

THE "Manual of the Geology of India" was some years out of print when a second edition was issued in 1893, dealing only with the general geology of the country. The equally important portion of the work, descriptive of the economic minerals found in India, could not be re-issued as a whole; the additions to our knowledge of the useful minerals are acquired in too irregular a manner, and, while parts of the original issue are to this day practically sufficient in their descriptions of the minerals found in India, others have been studied in a closer and more exhaustive manner.

For this reason it has been decided to re-issue Part III of the "Manual" in separate papers, each dealing with a single mineral, which could then be treated in greater detail and as exhaustively as circumstances permitted, and it is hoped that by these means it will ultimately be possible to complete the re-issue of the economic parts of the "Manual".

The exhaustive studies carried on by Messrs. Middlemiss and Holland assisted by Messrs. Warth, Smith and Hayden, who have been adding to our knowledge of the various forms of corundum found in India, have enabled Mr. Holland to compile the first part of a series descriptive of the more useful minerals of India. Mr. Holland also received much help from Drs. J. W. Evans and George Watt, C.I.E., and Mr. W. F. Petrie-Hay. In conclusion, grateful acknowledgments are due to the Royal Society, who courteously lent the blocks of map 3 and figures 5 and 6, being part of the illustrations in their Philosophical Transactions of the Memoir on the Burma Ruby by C. Barrington Brown and Professor J. W. Judd, C.B.

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CALCUTTA,

1st May 1898.

INDIAN CORUNDUM AND ITS VARIETIES, RUBY AND SAPPHIRE.

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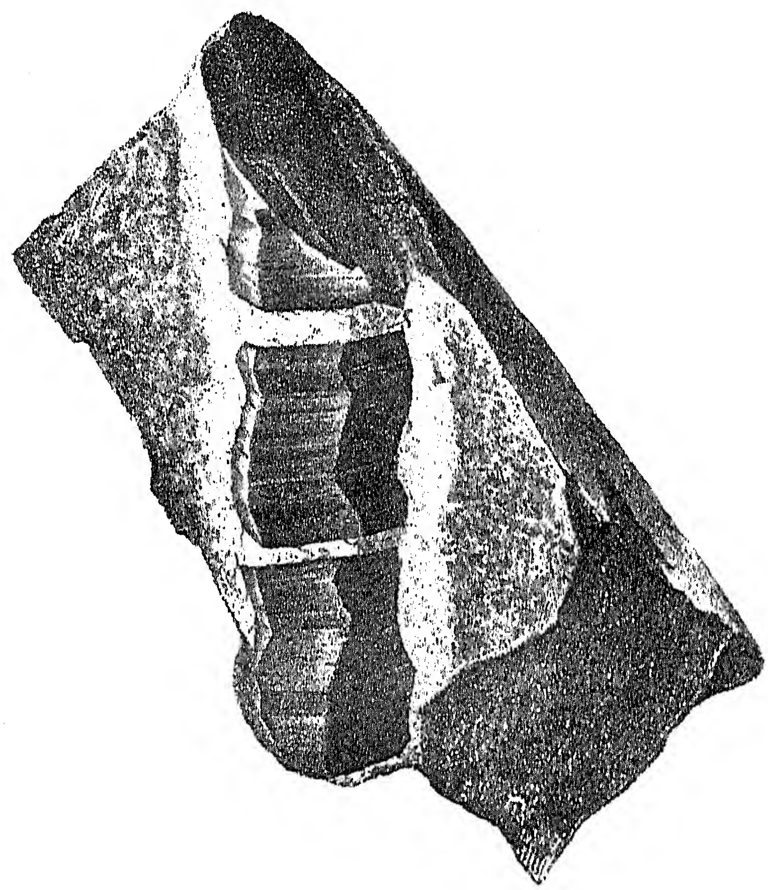
ECONOMIC GEOLOGY—CORUNDUM.

T. H. Holland. Frontispiece.



CRYSTAL OF CORUNDUM WITH ITS SHELL OF FELSPAR,
which also fills in the basal rifts.
From a large lenticle included in the Charnockite Series,
ERRANAHALLI, DHARMAPURI TALUK, SALEM DISTRICT.

ECONOMIC GEOLOGY

OF

INDIA.

No. 1. INDIAN CORUNDUM AND ITS VARIETIES, RUBY AND SAPPHIRE.

I.—INTRODUCTION.

THE Indian Empire can with very good reason be claimed as the home of corundum. The name *corundum*—under which the dull-coloured and non-transparent forms of natural alumina have generally been known since the introduction into Europe of a large number of Indian specimens towards the end of the last century—is only a modified form of the Sanskrit word *korund.*[1]

Not only are there large deposits in India of the common form of this mineral (the varieties separated under the name "imperfect corundum" in Count de Bournon's classical memoir[2]), but the most highly prized specimens of its transparent, red variety—the ruby—have been obtained from the famous mines of Burma, whilst the mines of Kashmir are noted for the size and transparency of the blue variety, sapphire.

As the great hardness of the common variety of this minerel creates for it a considerable demand as an abrading agent in metal-work and stone-cutting, both in India and Europe, it is not likely that it will for some time yet be used as a source of aluminium, although it is the richest natural compound of that metal. The very property which commands for corundum a large price as an abrading agent forms the principal objection to its replacing the poorer, but more easily worked, ores of aluminium as a source of the metal. But when the supplies of bauxite—the mineral which is now so largely used in the manufacture of aluminium—approach exhaustion, and when the use of the metal becomes, as seems most likely, more widely extended, there seems little doubt that processes will be devised for the elimination of the metal from corundum. As that time

[1] This mineral appears in Woodward's "Fossils of all kinds" (1728) as *corivindum*, a word probably derived from the *kuruvinda* of the Hindu Puránas, which, according to Raja Sir Sourindro Mohun Tagore (*Maní-Málá* (1879), pp. 187, 193, 197, 199, 203, 225 and 227), was a term used for a ruby of the second grade (*kshetriy caste*) from the Ràvanaganga of Ceylon.

[2] *Phil. Trans.*, 1802, p. 233.

seems still distant, it has been considered advisable to confine this part of the Manual to the treatment of the varieties of the mineral without regard to its relationships with the naturally occurring compounds of aluminium which are of value on account of their chemical composition only, and not, as in the case of corundum and its varieties, on account of their exceptional physical characters.

Amongst all the references in classical writings to the magical and medicinal properties attributed to the ruby and sapphire, the Purânas of the Hindus show that these beautiful gem-stones were nowhere better appreciated than in this their native country, which has, more than any other country in Asia, by its resources in natural products of beauty and utility, contributed to the mysterious charm which invariably attends the word "Oriental." There is no doubt that it is to the survival in a modified form of the ancient belief in the mystical power of these gems, apart from their intrinsic beauty, that they owe the esteem in which they are still regarded.

On account of their superior hardness, which facilitated the production of a more brilliant polish, the gem-stones, which, through the instrumentality of the East India Company, were transported from this country to Europe during the latter half of the last century, attracted the attention of the English lapidaries, who, without knowledge of the chemical and physical relations of the different minerals, gradually developed the habit of recognising these gems as *oriental varieties* of those with which they were previously more familiar in Europe. We have thus the *Oriental Topaz*, the *Oriental Emerald*, the *Oriental Aquamarine*, the *Oriental Amethyst*, and the *Oriental Ruby*. It was not until the publication of Count de Bournon's classical memoir that lapidaries, and mineralogists too, began to recognise that many of these, which were of Indian origin, were really only differently coloured varieties of the mineral *corundum*, which was at the time, and by the great mineralogist, Haüy, for some time after, placed with quite a different class of associates.

It is difficult to say when the identity of the ruby and sapphire was first suspected. King calls attention to the fact that Epiphanius (A. D. 400), deriving his information from some oriental source, classed the ruby and sapphire together, whilst Marbodus in the eleventh century included also the yellow variety, oriental topaz.[1] Mohammad Ben Mansur in the twelfth century classed together the different varieties of corundum on account of their hardness and specific gravity.

Romé de Lisle seems to have been the first to give any scientific reasons for grouping together the various forms of corundum; but it was left for Count de Bournon in 1802 to recognise by the similarity of chemical composition and essential physical characters, the close relationships of the ruby, sapphire, and common corundum, and to group them together

[1] King, Precious Stones (1865), p. 198.

as one species under the last name, the name which was suggested by Greville in 1798. The transparent, coloured forms used as gems he classed as "perfect" corundum, whilst those specimens which, through absence of colour and through the presence of numerous parting planes were useless for ornamental purposes, were described as "imperfect" corundum.

The two principal varieties of the "perfect corundum" are the *ruby* and the *sapphire*, both of which, connected with India, their principal source in olden times, were known to the ancients for their beauty and their supposed efficacy in medicine or in magic. The classic authors of Europe make frequent mention of the wonderful attributes of the ruby and sapphire brought from the East. The ruby was known to Theophrastus as 'Ἄνθραξ, because, from its blood-red colour, it was likened to a live coal, whilst Pliny in describing the family of "fiery" stones—the *Carbunculi*—separated the true ruby from the red garnets and spinels as the *Lychnis*,[1] the *Lychnites* of Solinus, who described its lustre, colour, electric and phosphorescent characters, and superior hardness, with a precision which leaves little doubt as to the identity of its mineralogical nature. The word *ruby* refers of course to the red colour of the gem-stone and was first employed about the year 1300 (Keferstein). It was referred to by mineralogists in the last century as the "Oriental" ruby, a term used to distinguish it from the red varieties of spinel and garnet, and equivalent in meaning to the "Indian" carbuncle referred to by Pliny to distinguish the true ruby from the other "fiery" stones.

King[2] argues that the *Hyacinthus* of the ancients was the mineral now known to us as sapphire, and quotes in support of his argument the following translation of a passage from Solinus, who was noticeably precise in his language concerning minerals :—"Amongst those things of which we have treated, is found also the Hyacinthus, of a shining sky-blue colour : a stone of price, if it be found without blemish ; for it is extremely subject to defects. For generally it is either diluted with violet or clouded with dark shades, or else melts away into a watery hue with too much whiteness .... This is the gem that feels the influence of the air, and sympathises with the heavens, and does not shine equally if the sky be cloudy or bright. Besides, when put in the mouth, it is colder than other stones. For engraving upon, indeed, it is by no means adapted, inasmuch as it defies all grinding ; it is not, however, entirely invincible, since it is engraved upon and cut into shape by means of the diamond." In the passage preceding this Solinus referred to the production of cinnamon in the same district from which the sapphire is obtained, probably referring to Ceylon, which is noted for its sapphires, and is geologically a continuation

[1] *Hist. Nat.*, Book XXXVII, Chap. VII (Holland's translation, p. 616).

[2] Precious stones and gems (1865), p. 193.

of the Indian peninsula. From his allusions to the hardness, density, and *aëreus color*, Pliny's term *Adamas Cyprius* evidently referred to the sapphire, and Epiphanius, who was a *Cyprian* bishop, applies the term ἀέριος to the *Adamas* which, according to his version, was the *Urim* and *Thummim*, which revealed God's will by its changes of colour.[1]

It is not improbable that Pliny's "*Nilion* found in India" was also a sapphire, the word referring to its blue colour as the Hindustani name of the mineral, *nílam*, does in India to-day.

The modern word "sapphire," which was used by the ancients for the blue mineral now known as *Lapis-lazuli*, refers merely to the colour of this variety of "precious" corundum, and appears to have been used in its modern sense at the close of the fifteenth century by Camillo Leonardo in his "Speculum Lapidum."[2]

[1] King, p 1896. | [2] King, p. 197.

II.—MINERALOGICAL CHARACTERS OF CORUNDUM.

Crystal form.

Corundum crystallizes in the hexagonal system in forms isomorphous with hematite, $Fe_2 O_3$, ilmenite, $(Fe, Ti)_2 O_3$, and pyrophanite, $(Mn, Ti)_2 O_3$. The Burma rubies, when they exhibit their crystal-form are generally combinations of the rhombohedron, basal planes and prism. The Kashmir sapphires, as well as the common corundums of Madras, often show the steep pyramidal planes in combination with the basal planes. The display of a tabular habit has been considered by Lagorio as a feature characteristic of corundum crystals which have separated from igneous fusion. Such tabular forms have recently been found in the Coimbatore district (*vide infra*, pp. 11 and 37). The crystals are often striated horizontally on the pyramidal faces and are frequently roughened and rounded, probably through corrosion by circulating solutions or reaction with adjoining minerals. The crystals are frequently twinned parallel to the rhombohedron, and the twins are often polysynthetic, giving rise to a lamellar structure.

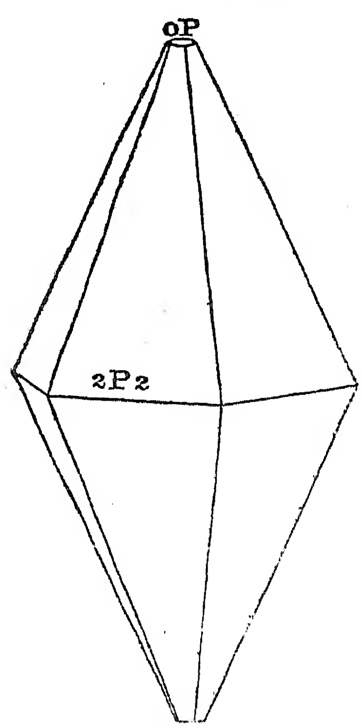


Fig 1. Sapphire from Zanskar, Kashmir (*after Mallet*).

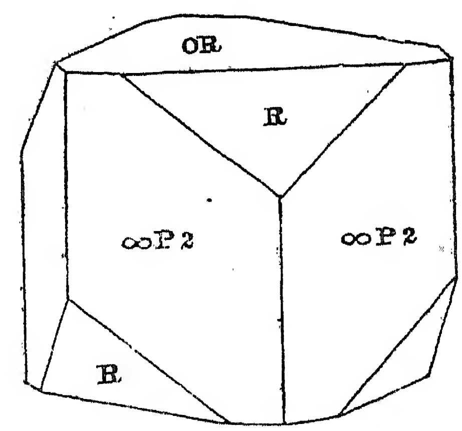


Fig. 2. Ruby from Jagdalak, Afghanistan (*after Mallet*).

Parting planes.

Whilst the transparent, blue sapphires break with a conchoidal fracture like that of quartz, and show no sign of cleavage planes, the commoner forms of corundum show a tendency to split parallel to the basal plane, the rhombohedron and, less easily, parallel to the hexagonal prism; but Professor Judd[1] has recently shown that these parting planes are not due to true cleavage, but to the fact that these directions, being gliding planes and twinning

[1] *Mineralogical Magazine*, Vol. XI., p. 49 (1895).

planes, become also "solution planes," along which the crystals exhibit a remarkable tendency to chemical change with the deposition of products of decomposition. It is to the formation of thin layers of these decomposition products that we must ascribe the pearly lustre of the so-called cleavage faces, the coincident diminution in the translucency of the mineral, and at the same time the great tendency to split in definite directions, when exposed to the mechanical stresses that corundum crystals must often be subjected to during the dynamical metamorphism of the hard crystalline rocks, which generally form the nidus of this mineral. It is to this cause that we must refer the destruction of the transparency of numerous crystals that are sufficiently coloured to form otherwise beautiful rubies and sapphires.

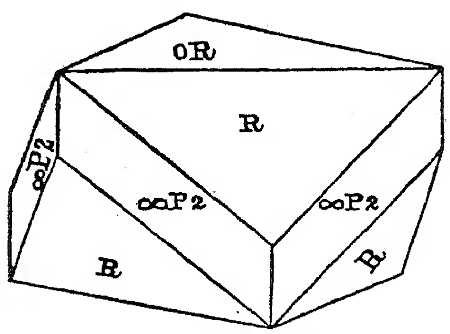


Fig. 3.

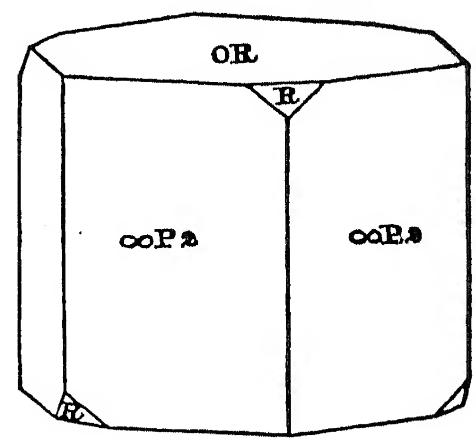


Fig. 4.

Rubies from Upper Burma (*after Mallet*).

Corrosion of crystals.

The peculiar "etch-figures," which are so frequently displayed on the basal terminations of corundum crystals, and the corrosion of the mineral into step-like forms, are ascribed to the same tendency to chemical change along definite crystallographic planes.

Specific gravity.

The specific gravity of corundum varies from 3·95 to 4·10, sapphire and ruby being very nearly 4; but the specific gravity decreases with the formation of decomposition products as described above. Of 16 different specimens of sapphire examined by Count de Bournon the average specific gravity was 4·016; of 20 specimens of ruby, 3·977; and of 33 specimens of common corundum, 3·931. He noticed that the specimens of the highest specific gravity were the transparent blue crystals, then the transparent red forms, and lastly the crystals which have lost their transparency through (according to Professor Judd) secondary formation of lighter products of chemical change.[1]

[1] Professor Judd gives 4·03 as the average specific gravity of the Burma ruby. *Phil. Trans.*, Vol. 187, p. 210 (1896).

Hardness.

Count de Bournon noticed also that these variations in specific gravity were perfectly in agreement with the variations in hardness—a conclusion which has since been abundantly confirmed by more exact quantitative estimations of the abrasive powers of the different varieties of the mineral. Corundum is, next to the diamond, the hardest mineral known, and represents degree 9 in Mohs' scale; but the varieties of this mineral vary amongst themselves. Sapphire will scratch the ruby, and the latter will scratch all the commoner forms of corundum (for abrasive power see page 52).

Decomposition.

The decomposition of corundum to form the hydrated oxides of aluminium, and subsequent silicification to produce various other minerals have been carefully studied by Drs. F. A. Genth and J. Lawrence Smith in America, whilst Professor Judd has recently traced out in detail similar changes in the rubies of Burma.[1] Many examples of common corundum appear to be intimate admixtures of the hydrous and anhydrous oxides of aluminium, a fact which accounts for the pseudo-cleavage, low specific gravity, as well as the inferior hardness, lustre, and transparency of the common ("imperfect") forms.

Colour.

The varieties of corundum differ very greatly in colour. The best Burma rubies are of a pure, deep red, the "pigeon's blood" of the jewellers; the typical sapphire is a deep blue, oriental emerald is green; the oriental topaz, yellow; and the oriental amethyst, purple. All these colours may be exhibited by the commoner forms, which also, on account of their incipient decomposition, may be brown, grey, or nearly white. Often crystals, especially the blue forms, are variegated in colour, sometimes with a zonal arrangement of the colour and at other times without discoverable regularity of distribution.

Pleochroism.

Longitudinal sections of transparent crystals of the coloured varieties when examined in polarised light show marked pleochroism. According to the direction of vibration of the polarised light the Burma ruby will vary from crimson to aurora-red, whilst the Siam ruby varies from crimson to brownish red; the Burma sapphire varies from blue to straw-yellow, the Siam sapphire from blue to green, whilst the purple varieties from Rewah vary from a rich purple to a very faint yellow.[2]

Asterism.

The phenomenon of *asterism* is exhibited when some forms of corundum are viewed in the direction of the vertical axis. This seems to be due in some cases to the development of rifts along the "parting planes" parallel to the hexagonal prism, and in other cases to the presence of numerous needles and plates of rutile mutually intersecting at angles of 60°, forming a "sagenite web."

[1] *Phil. Trans.*, Vol. 187, p. 218 (1896).

[2] Judd, *Mineralogical Magazine*, Vol. XI, p. 58 (1895); *Phil. Trans.*, Vol. 187, p. 210 (1896).

Varieties of sapphire exhibiting these phenomena are known as "Star-sapphires" (*Asteria* of Pliny).

Refraction.

Corundum possesses a high refractive index ($O = 1{\cdot}768$, $E = 1{\cdot}759$) and weak, negative, double refraction.

Phosphorescence.

An interesting property of the mineral is its rich red phosphorescence when heated or exposed to sunlight, from which property it is probable that the exaggerated accounts of the ruby shining in the dark have arisen. Mr. Mallet noticed this peculiar phosphorescence strongly displayed by the purple corundum of Rewah.[1]

Corundum is unaltered by heating before the blowpipe. It is dissolved slowly in fused borax or microcosmic salt forming a clear glass. When finely powdered and heated with nitrate of cobalt it gives a beautiful blue colour. It is not acted upon by acids or alkalies; but is converted into a soluble compound by fusion with bisulphate of potash.

Chemical composition.

Chemical analysis shows sapphires and rubies to contain at least 97·5 per cent. of pure alumina (Al_2O_3), the remainder being magnesia and silica; but how far the last-named substances are present as inclusions is not stated.

Distinctive characters of ruby, spinel, and garnet.

The red spinels which are found with rubies in the crystalline limestone of Burma so strikingly resemble the latter in colour that they are very frequently mistaken, and even sold, as rubies. As a rule, however, the spinels are well crystallized in the form of the octahedron, whilst the rubies are found either irregular in shape or showing hexagonal combinations. When examined in polarised light with a dichroiscope, longitudinal sections of rubies show the pleochroism already described, whilst the spinels are perfectly isotropic and non-dichroic. When possible the hardness will also serve as a means of discrimination, the ruby being sufficiently hard to scratch the spinel. Rubies, also, have a specific gravity of 4, whilst the red spinel seldom exceeds 3·6. With the heavy liquids recently invented such a test can be very easily applied. These minerals also show differences of behaviour before the blowpipe. Both become opaque when heated, but on cooling the ruby passes through a green stage before resuming its original colour. Red garnet may also be mistaken for both ruby and spinel, but may be detected by its fusibility before the blowpipe, its inferior hardness and its semi-resinous lustre.

According to recent researches by C. Doelter, ruby, spinel and garnet can be distinguished from one another by their relative degrees of translucency to the Röntgen X-rays. Whilst the ruby (as well as other forms of corundum) is practically transparent (degree 2 of Doelter), spinel is barely translucent (degree 5), and the garnet nearly opaque (degree 7) when

[1] *Rec. Geol. Surv., Ind.*, Vol. V, p. 21 (1872).

tested with the Röntgen rays.[1] The application of this test forms a convenient means for distinguishing the three minerals when mounted in jewellery.

The remaining precious forms of corundum—the oriental amethyst, oriental emerald, oriental topaz or yellow sapphire, and the oriental aquamarine—are of rare occurrence; but they have been recorded by Professor Judd as associated with the rubies of Burma,[2] and specimens of some of them are exhibited in the Geological Museum, Calcutta. All these varieties are so named from their resemblance in colour to the amethyst, emerald, topaz, and aquamarine, and can of course be distinguished by their superior hardness and specific gravity from the minerals known by these names (see page 2).

Detection of emery.

Without a careful examination in the laboratory emery might easily be mistaken for various other minerals and principally for iron-ore, of which it contains a large and variable proportion. Emery is also often confused with chromite, and still more so with the minerals pleonaste and hercynite, with which it is so frequently associated (*vide* p. 12). As an instance illustrating this latter case may be mentioned the fact that the late Professor G. H. Williams obtained the purest specimens of pleonaste from a pile of so-called "emery-ore" in the yard of a Peekskill emery mill.[3]

Average specimens of emery, however, exhibit a different fracture to that of iron-ore, and the fresh surface generally shows a lighter colour. Emery generally displays also a strong argillaceous odour when damped and scratches agate or quartz easily. The specific gravity also, though of course rather variable, should not be very much above or below 4.

Artificial production of corundum.

Aluminium oxide in the crystallized form has been prepared by numerous methods since the year 1869 when Gaudin fused the oxide in the oxy-hydrogen blowpipe-flame. One of the most successful has been the process which was adopted in 1877 by Frémy and Feil,[4] who heated aluminium oxide with minium (red oxide of lead) in a crucible, obtaining thereby fused aluminate of lead, which was decomposed by the silica of the crucible with formation of silicate of lead and free alumina, crystallized and exhibiting the other physical properties of corundum. By the addition of from 2 to 3 per cent. of potassic bichromate to the original charge the crystals of corundum became ruby-coloured, and by adding a small quantity of oxide of cobalt with the bichromate, sapphires were formed.

Fine artificial rubies have also been prepared by the action of barium fluoride at a red heat on amorphous aluminium oxide containing traces of bichromate of potash; but the artificially prepared crystals do not equal the natural gem-stones in beauty.

[1] *Neues Jahrbuch für Min.*, etc., 1896, Vol. II, p. 87.

[2] *Phil. Trans.*, Vol. 187 (1896), p. 210.

[3] *American Journal of Science*, 3rd Ser., Vol. XXXIII, p. 197 (1887).

[4] *Comptes rendus*, Vol. 85 (1877), p. 1029.

III.—GEOLOGICAL RELATIONS OF CORUNDUM.

To trace out with scientific precision its geological relationships and habits is the only safe basis for the economic development of any valuable mineral. In the mineral corundum we have a natural product which is not only valuable on account of its numerous and highly varied industrial applications, but one which, on account of its chemical composition, is of the deepest interest to the geologist. Alumina, of which corundum is composed, is, next to silica, the most abundant compound amongst the constituents of the Earth's crust, and with the latter substance forms a large number of the great group of silicates, thus becoming a considerable factor in nearly every geognostic problem. Careful study of the precise geological conditions under which corundum occurs should consequently yield not only useful results in guiding prospecting operations, but also data of the very greatest value to the student of chemical geology.

Until about ten years ago nearly all the known occurrences of corundum, common and precious, were in detrital material; but recently a large number of instances have been described of the mineral occurring *in situ*, especially in America, India, and Burma. Various explanations have been suggested for the origin of the mineral in each case; but so far as can be judged from descriptions of extra-Indian occurrences, and actual observations of those within the limits of the Indian Empire, the mineral seems to have crystallized in most cases as one of the earliest formed amongst the constituents of the rocks in which it occurs, together with its common associates, the spinelloids, ilmenite, rutile, and zircon—oxides which happened to be present in excess. Like all these early-formed oxides, corundum crystals generally present their proper crystal outlines (idiomorphic, *Rosenbusch*; automorphic, *Rohrbach*), except where destruction of the crystal form is the result of secondary alteration or corrosion. There appears to be no *á priori* reason why corundum, when occurring as a rock constituent, should require any different explanation than that generally applied to the other simple oxides occurring in a precisely similar manner, and Morozewicz has shown that it crystallizes directly according to Lagorio's law from a magma containing an excess of alumina (over 30 per cent. Al_2O_3) and may, or may not, be accompanied by spinels according to the proportion of other oxides present.[1]

The very common occurrence of alumina in combination with silica and other oxides to form the ordinary rock-forming minerals, and until recently the very limited number of known occurrences of corundum *in situ* may account for the tendency there is to regard the silicates as the natural home of alumina, and the uncombined oxide as the result of unusual or

[1] "Ueber die künstliche Darstellung von Spinell und Korund aus Silicatschmelzen." *Zeit. für Kryst.*, Vol. XXIV, p. 281 (1895).

secondary circumstances, such as contact metamorphism, action of so-called "mineralizing agents," or subsequent interaction between the constituents of previously formed normal (that is well-known) rocks.

Besides the occurrences recently recorded in India, corundum has been found in a large number of rocks of presumably igneous origin in various parts of Europe, America, and Australia. These include granites, pegmatites, diorites, trachytes, andesites, basalts, nephelinites, and peridotites.[1]

In many of the occurrences recorded, such as those in ejected blocks and inclusions, corundum may of course have been the result of contact action; but its occurrence as a constituent of normal lavas in the form of tabular crystals characteristic of those obtained artificially by Morozewicz during the devitrification of a slag, leaves no doubt as to the possibility of its free crystallization from an igneous magma, as is admitted for other simple, though commoner, free oxides. Even in such cases, however, the occurrence of corundum may be due to local, and in a sense, therefore, accidental, excess of alumina, and such is considered by the writer to be the case with the remarkable occurrence of corundum at Karutapalaiyam in the Coimbatore district, Madras, where tabular crystals of corundum are formed near the junction of a coarse felspar rock with a rock containing a large quantity of elæolite (see p. 37). The automorphic, tabular crystals of corundum occurring in the coarse felspar rock recall those obtained by Morozewicz in a slag containing an excess of alumina (over 30 per cent.), and judging only by specimens one might well be tempted to regard them as normal original constituents (*cf.* Middlemiss, *Rec. Geol. Surv. Ind.*, Vol. XXIX, p. 48); but field-observations show the distribution of the corundum to be restricted to the vicinity of the elæolite-bearing rock, which contains an excess of alumina. So here again the conditions are exceptional, and they are of a kind which are very liable to give rise to misunderstanding in valuing the terms, primary and secondary. That its formation may also be brought about by more indirect means, such as those recently traced out by Professor Judd in the case of the ruby, and thus become a secondary mineral, does not affect the argument in favour of the primary occurrence of corundum any more than in the case of quartz or other well-known constituents of common igneous rocks.

Occurrence of Indian corundum.

The principal Indian occurrences of corundum *in situ* can be divided into two classes: (1) those in which corundum is associated with *basic* rocks, and (2) those in which its associates are distinctly silicious (*acid*). Both classes are well represented in India, but in most cases where corundum has been found associated with basic rocks, intrusions of pegmatite have also been found in the neighbourhood.

[1] *Cf.* Lagorio, "Pyrogener Korund, dessen Verbreitung und Herkunft," *Zeitschr. für Kryst.*, Vol. XXIV, pp. 285—296 (1895).

Association of Corundum with basic rocks.

Amongst the associations of corundum with basic rocks the most common are those in which pyroxene is a predominant constituent, associated with some member of the spinel group, which serves as an index to divide these occurrences of corundum into three main groups:—

(1) The *ferruginous group*, in which the pyroxene is the highly ferriferous enstatite (hypersthene or amblystegite) and the spinel either hercynite ($FeO.Al_2O_3$) or hercynite with magnetite ($FeO.Fe_2O_3$). With this group ilmenite, $(Fe,Ti)_2O_3$, may be found largely replacing corundum (Al_2O_3).

(2) The *ferro-magnesian group*, in which the ferrous oxide may be more largely replaced by magnesia, with the result that a less ferriferous enstatite is associated with pleonaste, $(Mg. Fe)O.Al_2O_3$. With this group we should expect sometimes to find olivine, $2(Fe,Mg)O.SiO_2$.

(3) The *magnesian group* in which iron compounds occur in very small quantities and the spinelloid is ruby-spinel, $MgO.Al_2O_3$. With this group we should expect the more magnesian types of olivine and as secondary minerals, talc, dolomite, and magnesite.

As might be expected, the isomorphous protoxides of iron and magnesia replace one another by insensible gradations, with the result that we find in some areas the rocks may be found to combine the chemical characters of any two of the above groups.

Corundum and hercynite (pleonaste) with pyroxenic rocks.

An occurrence of corundum associated with the minerals of the first and second groups was discovered by the writer in 1892 at a point one mile east-south-east of Singanamaranhalli in the Hunsur taluk of Mysore State. At this point also there has been an intrusion of olivine-bearing rocks (peridotites) similar to those occurring in the Chalk Hills of Salem district, Madras Presidency, which have in like manner been decomposed with the development of veins of magnesite, chalcedony, and serpentine. The pyroxenic rock forms a hill adjoining the peridotites and the main deposits of corundum, and consists of hypersthene, sometimes with fibrolite, and a green spinel in which magnetite is scattered as black dust, or as large octahedral segregations around which the black dust has been cleared in a manner precisely similar to the clear zones which surround the magnetite granules in tachylytes blackened by disseminated magnetite dust. The association of corundum in this area recalls the very similar geological conditions of the magnetic iron-ore and emery deposits of the Cortlandt norites described by the late Professor G. H. Williams,[1] which were found

[1] *American Journal of Science*, Vol. XXXIII, p. 194 (1887).

to contain large quantities of a similar green spinel representing a type intermediate in composition between pleonaste and hercynite. A very similar association of corundum and hercynite occurs near Ronsberg on the eastern edge of the Bohemian Forest[1]—the original locality from which Zippe described the first specimens of the latter mineral in 1839.[2] A further interesting fact in connection with this subject is the association of fibrolite (the silicate of alumina) with hercynite near the same locality in Mysore, near the emery mines of the Cortlandt series of New York, and in the similar Saxon granulites described in the memoir by Kalkowsky quoted above.[3]

As directly bearing on this association of corundum with hercynite should be mentioned Dr. Genth's description of a spinel intermediate between hercynite and pleonaste pseudomorphous after the corundum and said to have been brought from India.[4] Somewhat similar crystals have been found by the author in the Erode taluk, Coimbatore district, Madras, where platy crystals of green spinel, measuring sometimes an inch across, were found on fracture to have cores of pink corundum.[5] Several similar instances have lately been found by Mr. Middlemiss in the Salem district.

The similarity of mineral association which has been noticed in the three localities just referred to is still further accentuated when we take the neighbouring rocks into consideration. About the most abundant amongst the massive rocks of the Madras Presidency are a series of pyroxene-bearing granulites (the charnockite series) in which the rhombic pyroxene, hypersthene, is a constant constituent. Although, as the result of a few hasty tours in South India, the author knows of no further instances than that in Mysore showing an actual association of this interesting series of rocks with corundum[6] it would not be surprising to find on further research many cases similar to that of the Cortlandt series of New York, where Professor Williams has shown the intimate

[1] Kalkowsky, *Zeitschr. der deutschen geol. Gesellschaft*, Vol. XXXIII (1881), p. 536.

[2] *Verh. der Gesellsch. des Vaterländ. Museums*, 1839.

[3] *Zeitschr. d. d. geol. Ges.*, Vol. XXXIII (1881), p. 537.

[4] *Proc. Amer. Phil. Soc.*, Vol. XIII, p. 369 (1873).

[5] On account of the hardness of hercynite (and of other spinels, too, for that matter) it is frequently mixed, often unknowingly, with emery and sold as such.

[6] Amongst the specimens collected by the author during a rapid trip across the "Chalk Hills," in Salem district, there was one of a fine-grained, granulitic, pyroxenic rock with much magnetite and hercynite, near the dunite instrusions. The conditions in this locality so closely resemble those of the Singanamaranhalli corundum-bearing area of Mysore that the discovery of corundum near the contact of the ultra-basic rocks with the pyroxenic series of the Chalk Hills seems by no means improbable. There seems to be no reason why alumina should not replace ferric oxide in the ordinary magnetite and produce hercynite, or further to occur in sufficient quantity to crystallize out free in the form of corundum. [Since the above was written, it has been found that the large corundiferous lenticles of the Erranahalli trial pits in the Paparapatti area, Salem district, are included in the pyroxene granulites (charnockite series) and along the corundum belt large quantities of hercynite lumps, often with cores of corundum, have been picked up.]

connection of the emery deposits with a set of rocks most strikingly like the pyroxenic series of Madras.[1]

From the descriptions of such authors as Kalkowsky, Naumann, Credner and Zirkel, and the subsequent elaborate researches of J. Lehmann, it is evident that some of the Saxon pyroxene-granulites, in which hercynite is widely distributed, are also very similar to those of the Madras Presidency.

Ruby and ruby-spinel in limestone.

The Burma ruby may be regarded as an example of the third group, being an occurrence of corundum in basic rocks, associated also with a magnesia-alumina spinel—the spinel which, from its constant presence, Tavernier speaks of as the "mother of ruby." In this area also we find a series of pyroxenic rocks similar to those of the Madras Presidency. Mr. Barrington Brown was the first to prove the existence of the ruby *in situ* in the crystalline limestones, which are found intercalated with various types of gneisses in the Mogok area, Upper Burma.

The crystalline limestones, whose petrological characters have been worked out in detail by Professor Judd,[2] are sometimes dolomitic and contain a large number of accessory minerals, some of which are peculiar and some identical with those found in the associated basic gneisses, pyroxenites and amphibolites. In the former class we have, besides the ruby, phlogopite, wollastonite, spinel, pyrrhotite, diaspore, hematite, limonite, apatite (moroxite), and graphite, whilst in the latter class there are diopside, augite (diallage), sahlite, enstatite, bronzite, hypersthene, quartz, orthoclase (murchisonite and moonstone), oligoclase, anorthite, basaltic hornblende, biotite, fuchsite, scapolite, zircon, magnetite, titanoferrite, sphene, rutile, and garnet. Professor Judd has remarked the absence from these limestones of minerals like chondrodite and tourmaline containing fluorine and boric acid—minerals which are found in the corundiferous limestones described in other parts of the world. Large crystals of chondrodite, however, do occur in the ruby-bearing crystalline limestone of Sagyin, 60 miles south-south-west of the Mogok ruby-mines, and 16 miles north of Mandalay.

Pegmatite associated with corundum.

The most interesting features in connection with this occurrence of corundum are the intimate association of the limestone with a pegmatite, which Mr. Middlemiss has shown to be a constant feature also in the Madras corundum-deposits, with biotite-gneiss, and especially with the remarkable pyroxene-granulites, similar to those which occur in such great abundance in the Madras Presidency and are characterised by the constant presence of a rhombic

[1] The author is greatly indebted to Professor J. W. Judd, C.B., F.R.S., for a set of slides of norites and associated rocks of the Cortlandt series described by Professor G. H. Williams, and for the privilege of examining a number of specimens illustrating the papers by the latter author which appeared in the *American Journal of Science* during 1886 and 1887.

[2] *Phil. Trans.*, Vol. 187, p. 151 (1896).

pyroxene approaching hypersthene in composition. Titanium-bearing minerals and zircon also are remarkably abundant in both the Madras and the Burma pyroxene-granulites.

Origin of the ruby-bearing limestones.

Professor Judd has described the development of scapolite at the expense of the basic plagioclase in these granulites, and has cited cases showing the development of the rhombohedral carbonates in these, giving various gradations from the simple pyroxene-granulite, through types in which calcite occurs in subordinate quantities, to the calciphyres, which contain the ruby and spinel amongst other accessory minerals. In the absence of evidence pointing to their organic origin, the limestones are thus regarded as extreme forms of the alteration of rocks which are now generally regarded as igneous in origin.

The graphite, so abundant in these limestones, has been looked upon as the representative of the carbon in the original organic limestone; but it has been found by the author in large quantities disseminated through very fresh specimens of a pyroxene granulite at Pallavaram, near Madras, and more recently in elæolite syenite in Coimbatore (p. 37).

It is interesting to find similar limestones associated with the same pyroxenic rocks in Ceylon, which is geologically a continuation of the Madras Presidency, and which is as noted as the Indian dominions for its precious forms of corundum. Lacroix describes magnesian cipolins from Ceylon in which, besides phlogopite, there occur spinel, pyrrhotite and chondrodite, being thus similar to the Sagyin limestones.

Corundum and indianite.

In view of Professor Judd's conclusions concerning the origin of the corundiferous limestones it seems appropriate to link with them the anorthite rock (indianite) containing corundum in the Salem district of Madras, which is famous for being the material used by Count de Bournon for his memoir on corundum. These rocks have recently been made the subject of microscopic study by M. A. Lacroix, who has confirmed the identification of anorthite (indianite) and has pointed out the occurrence, in the same rock, of hornblende, garnet, scapolite, pyroxene, epidote and a new mineral, to which he has given the name fouqueite, and which he regards as a dimorphous form of zoisite. In a similar rock from Ceylon, Lacroix adds sphene and calcite to the list of constituents.

Although the anorthite matrix was the first-described amongst the occurrences of corundum, this association appears to be rare, possibly because the anorthite has in many other cases been changed to carbonate of lime. It is interesting to note in this connection that in the Urals, blue corundum has been found in barsowite—a mineral having the chemical composition of anorthite, often intimately mixed with calcite, and enclosing also spinel and an occasional scale of a yellow mica.

The remarkable purple corundum of South Rewah appears from

Mr. Mallet's description[1] to form a thick bed, associated with euphyllite (fuchsite) a chromiferous mica, schorl, rutile and chrome spinel (picotite) in coffee-coloured grains (Judd). It is interbanded with a porphyritic gneiss and hornblende rock with jade and tremolitic quartz schists. But not far from the corundum deposits there occur bands of crystalline dolomite and limestone with serpentine. Until the exact petrographical relations of these beds to the corundum have been made out, the Rewah purple corundum may be retained in the group of corundum occurrences with basic associates. The beautiful green mica occurring with the Rewah corundum appears to be similar to the fuchsite found by Professor Judd in the ruby-bearing limestone of Burma,[2] and to the euphyllite found associated with tourmaline and corundum at Unionville, Delaware Co., Pennsylvania[3]. Dr. J. Lawrence Smith[4] also refers to euphyllite, with a query, found by him in the emery deposits of Asia Minor.

Purple corundum with chrome-bearing minerals.

Association of Corundum with acid rocks.

Sapphires in granite.

The sapphires of Kashmir occurring in a granite, form a good example of the occurrence of corundum in rocks of acid composition (p. 34). They are associated with a coarse schistose gneiss, containing white felspar and much black mica, having portions crowded with deep-red and brown garnets. On the northern side of the valley a bed of coarsely crystalline silicious limestone, about 100 feet thick, is intercalated with the gneiss. Also interbedded with the gneiss are several large masses of a fibrous felted kupfferite (anthophyllite) of a grey or green colour. The masses of this mineral are from 20 to 30 and in one case quite 100 feet thick.

The gneiss is traversed by numerous veins of coarse-grained granite (pegmatite) in which, besides the quartz, felspar and smaller quantities of dark-coloured mica, there occur well developed crystals of tourmaline, light green euclase, kyanite, minute red garnets and crystals of sapphire. These last are associated with a plagioclase felspar in portions of the rock having a miarolitic structure. Amongst other minerals found in this corundiferous granite were green tourmaline, cookeite, spodumene and prehnite. Beryl and lapis-lazuli are found in the neighbourhood.

Possibly in this group should be placed the blue corundum which, with kyanite and damourite, forms a vein three feet thick lying near, and running parallel to, the boundary and the foliation-strike of the rocks, between

[1] *Rec. Geol. Surv. Ind.*, Vol. V, p. 19 (1872), and Vol. VI, p. 42.

[2] *Phil. Trans.*, Vol. 187, p. 213 (1896).

[3] Smith and Brush, *Amer. Journ. Sci.*, Vol. XV, p. 209 (1853).

[4] *Amer. Journ. Sci.*, Vol. XI, p. 62 (1851), and Vol. XV, p. 210 (1853).

the transitions and the crystallines near Balarampur in the Mánbhúm district of Bengal (*vide infra*. p. 21). According to Dr. Warth, the kyanite-corundum vein and micaceous beds lie in a coarse-grained quartz rock, in which there are large quantities of black tourmaline, and which has been penetrated by numerous veins of graphic granite. Rutile crystals with faces well developed were picked up at the surface, but were not found *in situ*.

Blue corundum and kyanite.

The corundum crystals are generally of a deep blue colour, sometimes variegated by white spots, particularly in their centres, and are often distinctly zoned by alternate layers of blue and white mineral. They vary in size from minute granules to crystals weighing 3 lbs. in weight, and nearly always show a hexagonal outline in cross section, with fairly smooth prism faces. They lie without any discoverable crystallographic regularity in the large crystals of pale blue kyanite, from which they are often separated by a thin layer of pearly damourite. The kyanite crystals show the usual platy structure and are often greatly distorted and curved. The way in which the scaly mica separating the corundum from the kyanite passes gradually into the latter mineral suggests its secondary origin by the introduction of hydrous potash orthosilicate, or its constituents.

A very similar occurrence of blue corundum was discovered by Mr. W. B. Rucker in 1888 near Bull Mountain, Patrick county, Virginia, the specimens of which were described by Dr. F. A. Genth.[1] The rocks *near* the corundum-bearing area appeared to be various forms of schists and slates intersected by several granite dykes, between the outcrops of which, at the surface, the blue corundum, kyanite, mica, andalusite, and chloritoid were found. No serpentine or chrysolite rocks were observed in connection with this corundum. According to Dr. Genth the minerals andalusite, kyanite, mica and chloritoid are derived by alteration of the corundum, but although the description of the relations of these minerals might apply very well to the Mánbhúm occurrence, I could not satisfy myself that the latter showed any proof that the hexagonal crystals of blue corundum are mere remnants of larger masses which had been changed into the great bladed crystals of kyanite, sometimes 9 inches long, and in which they lie without any regularity of crystallographic disposition. If such large quantities of kyanite, which is far in excess of the corundum, had been derived from the latter mineral, and if the latter are the mere remnants of larger crystals, it is very remarkable that the crystal-faces are still so regularly displayed. It is, judging from analogy, highly improbable that such an amount of "etching" could take place without destroying the crystal outlines of the corundum, especially of the prism faces. It seems to me a far simpler explanation to regard the idiomorphic corundum crystals as the earliest-formed mineral in the rock, whilst it subsequently

[1] *Amer. Journ. Sci.*, 3rd ser., Vol. XXXIX, p. 47 (1890).

became enveloped by the kyanite, which has been partially changed to mica by the introduction of potash and silica, the latter being partly crystallized also in small quantities as free quartz. Whatever may have been the precise physical conditions under which this crystallization took place whether of igneous or aquo-igneous fusion, or whether the little-understood so-called hydrothermal infiltration, there is no doubt that the conditions were favourable to free molecular movement and that the order of crystallization was in accordance with the more frequent order of the formation of our common crystalline rocks—the excess of simple base was first separated, and was followed by the formation of a compound of the remainder of that base with silica.

Corundum, sillimanite and andalusite.

Corundum has been found by Lacroix associated with sillimanite, andalusite and rutile in some rocks from Salem and Ceylon, similar to the andalusite-bearing "granulites" (pegmatites) found by the same author piercing the gneiss of the Pyrenees of Ariège.

Corundum, and orthoclase.

As an example of an occurrence with the silicious minerals, the discovery of corundum and sillimanite (fibrolite) embedded in orthoclase in the Paparapatti area of the Salem district of Madras (*vide* p. 41) appears to be unique. The lenticles composed largely of flesh-coloured orthoclase are sometimes as much as 15 feet long, and occur in a pyroxene-granulite, which has been penetrated by veins of pegmatite. The corundiferous lenticles are apparently distributed along a band not far from the junction of the pyroxene-granulites (charnockite series) with a rock related to the foliated biotite-granite which is so largely developed in the Hosur and Krishnagiri taluks (Hosur gneiss of Middlemiss). The geological relations of these two groups of rocks have not yet been fully worked out, but the occurrence of the corundum so near the junction suggests its origin as the result of contact action, and the presence of sillimanite in the lenticles with it adds weight to this suggestion. With the large crystals of corundum there occur in the felspathic lenticle, smaller crystals of the same mineral, with sillimanite (fibrolite), rutile, translucent green and opaque black spinelloids, and biotite, which is especially abundant near the periphery of each lenticle. A very interesting feature is the pink or white shell extending from $\frac{1}{8}$th to $\frac{1}{4}$ inch around each large crystal of corundum (see frontispiece). This shell is nearly devoid of the small accessory minerals, and is quite free of the minute corundums and sillimanites. The excess of alumina has thus been

removed from the immediate precincts of each corundum crystal and so forms a very pretty illustration of a crystal "court." The outline of this crystal court is rendered all the more distinct by the fact that the felspar is generally coarser in grain in the immediate neighbourhood of the large corundum crystals, a fact which has an interesting bearing on our conclusions as to the mode of formation of the latter mineral.

IV.—GEOGRAPHICAL DISTRIBUTION OF INDIAN CORUNDUM.

The corundum deposits of the Madras Presidency, having furnished the material investigated by Count de Bournon for his classical memoir on the different varieties of this mineral, are the widest known occurrences of the common variety, whilst for the precious red variety—ruby—Burma has been famous since the days of Tavernier. The Provinces and Native States in which corundum has been found are arranged below in alphabetical order as follows :—

AFGHANISTAN.
ASSAM (Khasi Hills).
BENGAL—
  Manbhum district.
  Monghyr ,,
BURMA—
  Mainglon State.
  Mogok area.
  Nanyetseik.
  Sagyin.
CENTRAL PROVINCES.
HYDERABAD.
KASHMIR.
MADRAS—
  Anantapur district.
  Coimbatore ,,
  Kistna and Godavari.
  North Arcot.
  Salem.
  South Kanara.
MYSORE.
PUNJAB.
REWAH.
TRAVANCORE.

AFGHÁNISTÁN.

Rubies occur in a crystalline, micaceous limestone (cipollino), apparently similar in character to the crystalline limestones of Burma, at Jagdalak, 32 miles east of Kábul. Two crystals of these rubies presented by Major Stewart, and now in the Geological Museum, Calcutta, show the combination $\infty P2.\ oR.\ R.$ and respectively weigh rather more than 1 and $1\frac{1}{2}$ carats; but Mr. Mallet,[1] who made these determinations, records having seen one considerably larger. Mr. Streeter[2] mentions having possessed a ruby weighing $10\frac{1}{2}$ carats from the mines of Gandamak, which is about 20 miles from Jagdalak.

[1] Manual, Geology of India, Part IV (Mineralogy), (1887), p. 45. These rubies have been erroneously described as spinels in *Proc. As. Soc., Beng.*, 1880, p. 4, but were determined to be true rubies by Mr. Mallet. The writer has confirmed this determination by goniometric measurement of the crystals.

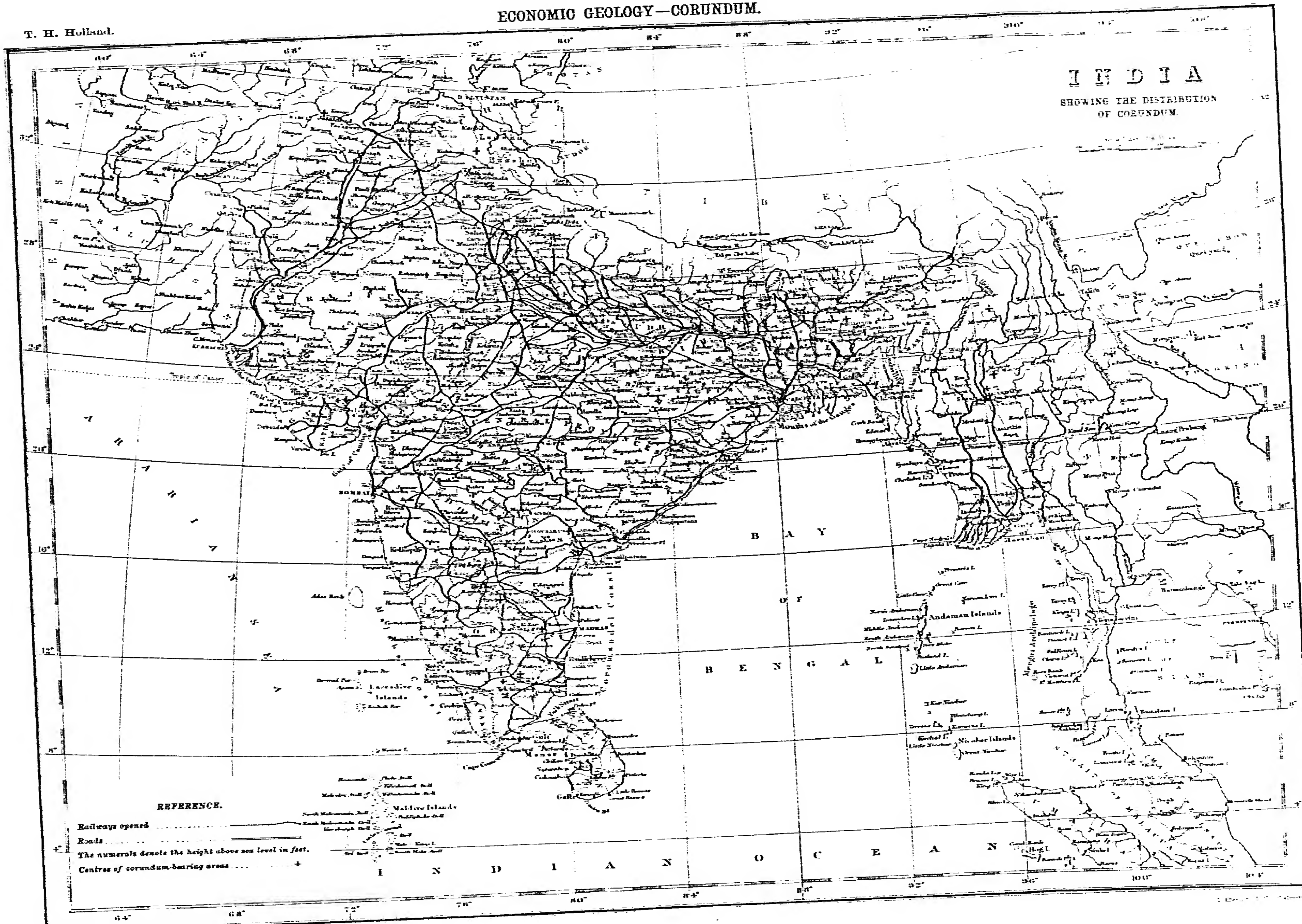
[2] Precious stones and gems, 4th Ed. (1884), p. 161.

GEOLOGICAL SURVEY OF INDIA.

MAP No. 1.

ECONOMIC GEOLOGY—CORUNDUM.

T. H. Holland.



Reg. No. 416, Dir., Geol. Sur.—Nov. 97.—700.

The unaltered limestones of Jagdalak were identified by Mr. C. L. Griesbach[1] with the carboniferous, and considered to be an outlier of the Attock slate series. The crystalline limestone, he informs the writer, are unquestionably sedimentary limestones metamorphosed by the numerous intrusions of granite which ramify amongst them. Highly contorted gneissose rocks are also recorded by Mr. Griesbach in the same locality.[2]

ASSAM.

KHÁSI HILLS.

Mr. F. R. Mallet,[3] late Superintendent, Geological Survey of India, has described a large specimen of massive rock-corundum from the village of Nongryniew, two days' journey north-west of Nongstoin, the capital of a petty Khasi State (lat. 25° 31′, long. 91° 20′). There is no exact information concerning the mode of occurrence of the rock, which, it seems, is picked up as rounded lumps by the villagers who use it for grindstones. As the hills near this village are within 15 miles of the Brahmaputra river, the cost of carriage would not be a drawback to the development of this corundum should it occur in quantity as the specimen suggests.

It is a finely granular, light-grey, or greyish-white rock containing microscopic granules of a translucent, dark-red mineral (probably rutile), and has a specific gravity of 3·93.

BENGAL.

MÁNBHÚM DISTRICT.

A valuable deposit of blue corundum with kyanite was discovered in 1895 by Dr. H. Warth, late Deputy Superintendent, Geological Survey of India, in a road-cutting near the village of Salbanni, four miles east-south-east of Balarampur, Bengal-Nagpur Railway.

The vein, which is about 3 feet thick, follows the strike of the rocks and the boundary line between the transitions and metamorphics, running a little to the south of east, and is traceable at intervals for six miles. This boundary is formed by a fault rock of pseudomorphic, and sometimes massive, quartz, which contains much limonite and in some places copper ore.

The kyanite occurs with micaceous beds in coarse-grained quartz-rock, which forms here a slightly elevated broad ridge parallel and close to the boundary, about one-fourth of a mile to the north of the ridge of fine-grained splintery quartzite with which the transition rocks terminate.

The coarse-grained quartz-rock contains much tourmaline, rendering whole beds of the quartz banded or entirely black. Tourmaline is also

[1] *Rec., Geol. Surv., Ind.*, Vol. XX, p. 97 (1887).

[2] *Ibid.*, p. 24.

[3] *Rec., Geol. Surv., Ind.*, Vol. XII, p. 172 (1879).

abundant in the quartzite which extends about one mile further from the kyanite-corundum vein on the side of the metamorphics (see also p. 16).

MONGHYR DISTRICT.

Corundum is said to occur in the hills north-east of Jamui in Monghyr district and has been so marked by Captain Sherwill in his geological map of Bengal,[1] but Mr. C. R. Marriott, C.S., the Collector of Monghyr, informs me that enquiries made by the Sub-Divisional Officer of Jamui failed to confirm this statement.

BURMA.

Since about the end of the fifteenth century Burma has been famous in Europe for its rubies. An account, from hear-say, is given by Jean Baptiste Tavernier in his "Travels."[2] Since Tavernier's time accounts of the mines have been published by Mr. Crawford[3]; Père Giuseppe d'Amato[4] who visited the mines sometime before 1833; Dr. T. Oldham,[5] who collected information whilst with Sir Arthur Phayre's mission to the Court of Ava in 1855; Mr. Spears,[6] and Mr. Bredemeyer, who was in the service of the King of Burma in 1868, and visited some, but not the principal, ruby-mines.

Various accounts have been given of the size of rubies which have been obtained in the past in Burma; but it appears difficult to correctly estimate the value of the accounts gathered by hear-say. According to official returns the King of Burma derived an annual revenue of about R90,000, to R100,000 annually from the ruby-mines, besides stones above a certain size, which according to order were reserved for the King.

Besides rubies, Mr. Crawford and others mention the occurrence with the ruby of sapphire, oriental topaz, oriental amethyst, oriental emerald, and girasol sapphire. This statement has been confirmed recently by Mr. Barrington Brown and Professor Judd.

The ruby-bearing rocks extend over a large portion of Upper Burma chiefly on the eastern side of the Irrawaddy, and from thence into the Shan States, the principal centres being :—

MAINGLÔN STATE.
MOGOK AREA (THE RUBY MINES).
NANYETSEIK.
SAGYIN.

[1] Statistical account of Bengal, Vol. XV, p. 31 (1877).

[2] Translation by Ball (1889), p. 99.

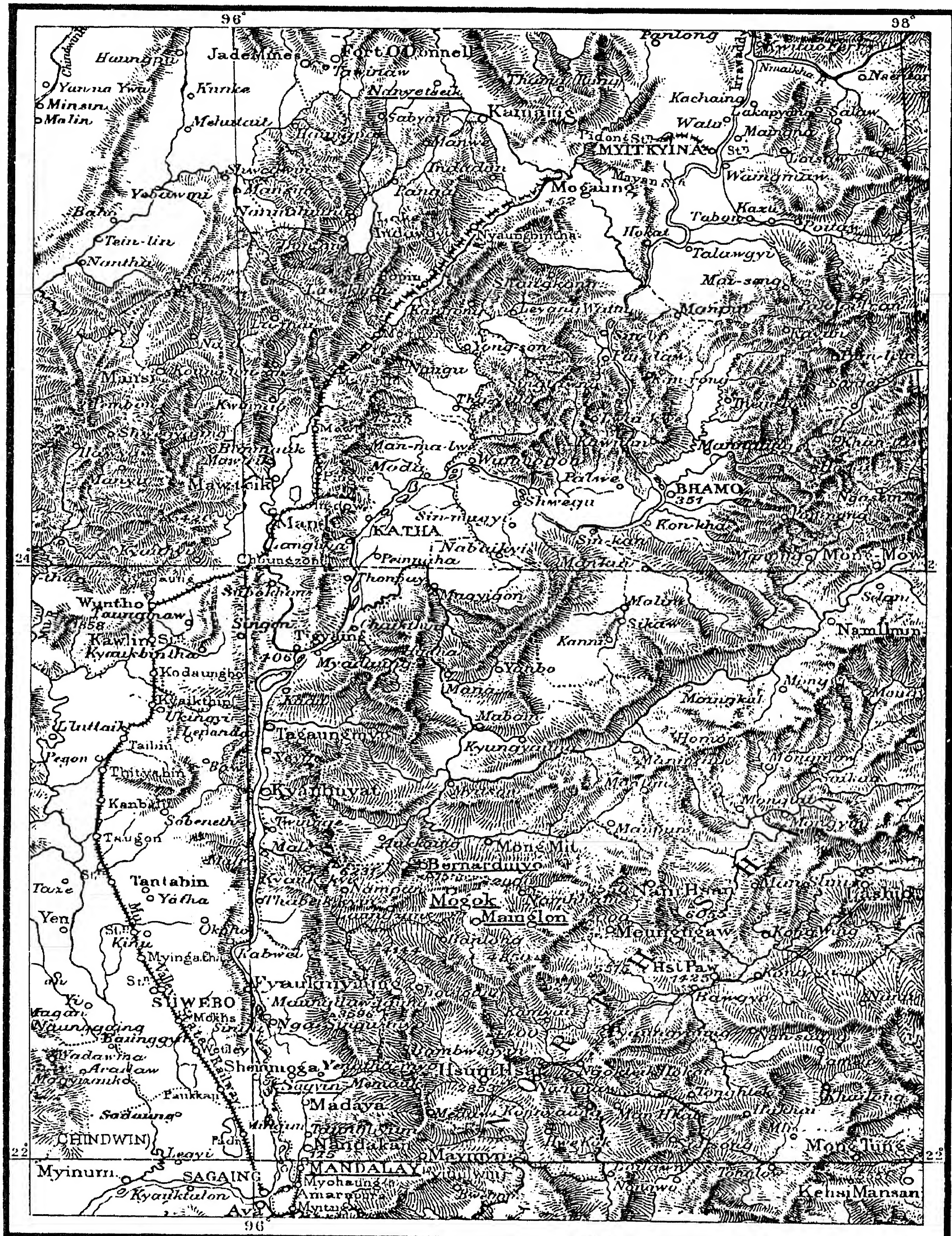
[3] *Edinb. New Phil. Journ.*, 1827, p. 366.

[4] *Journ., As. Soc., Bengal,* Vol. II, p. 75 (1833).

[5] Yule's Narrative of the Mission, p. 347 (1858).

[6] Quoted in Dr. Oldham's report already referred to.

T. H. Holland. MAP No. 2 Corundum.



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Litho., S. I. O. Calcutta.

DISTRIBUTION OF PRECIOUS CORUNDUM IN UPPER BURMA.

Names of places from which Corundum has been reported are underlined.

MAINGLON STATE.

Valuable rubies are reported to have been found in the river-gravels of the Nampai valley near Namséka village, 15 miles south-west of Mainglôn (lat. 22° 46′; long. 96° 44′). Dr. F. Noetling[1] suggests that these, if the report be reliable, may have been brought down by the Mogôk stream from the ruby-mines area. He found spinels, tourmalines, etc., in these gravels, where a large excavation had been made, but obtained no rubies.

MOGOK RUBY-MINES.[2]

The principal ruby-mines of Burma are situated in a hilly region about 90 miles north-north-west of Mandalay, elevated between 4,000 and 5,500 feet above the sea. The chief workings are situated in the Kathay, Kyatphyen, and Mogôk valleys; and cover an area of about 66 square miles.

The rubies are found in—

(*a*) Crystalline limestone.
(*b*) Hill-wash.
(*c*) Alluvium.

(*a*) *Crystalline limestone.*

The gem mines of Upper Burma are situated along the outcrops of the crystalline limestone which is associated with, and forms an integral part of, the gneissic rocks of this area, and which, Mr. Brown first showed, is the parent rock of the ruby. Interfoliated with the gneisses are numerous bands of pegmatite, a feature of interest from the persistent occurrence of the same rock in the neighbourhood of the corundum deposits of Madras and elsewhere.

According to Mr. Barrington Brown, the outcrops of this rock are easily discerned crossing the mountain sides and spurs of the open portions of the country, in the form of dark-grey masses rising above the surface of the enclosing gneiss. Their true white colour is completely disguised by a dark-grey lichen, which coats and clings tenaciously to their surface. In many parts of the mountain slopes their continuity is hidden by the thick covering of hill-wash; while in the valley bottoms they are covered by deposits of alluvium, where they are often exposed by the mining operations.

[1] Note on the reported Namsèka Ruby-mine in the Mainglôn State, *Rec., Geol. Surv. of Ind.*, Vol. XXIV, p. 119 (1891).

[2] For the information concerning these mines the author has drawn almost entirely from the interesting memoir recently written by Mr. C. Barrington Brown, F.G.S., and Professor J. W. Judd, C.B., F.R.S., and published by the Royal Society (*Phil. Trans.*, Vol. 187, p. 151 (1896).

The surface of the limestone is carved into various shapes by the action of the weather, whilst caverns and "swallow holes" are often formed of considerable size.

There are eleven distinct exposures of limestone between the falls on the Mogokchoung and the peak next below Toungnee on the southern slope of that mountain. The principal band, No. 3, along which the most important mines are situated, is some 300 feet in width, and, as far as it can be made out, extends in a sinuous line from Dattau through the end of Letnytaung spur, on the edge of Mogôk valley, onwards in a westerly direction through Bobadaung. There it curves in a south-westerly direction past Pyanbin to Pingu hill, where its course is altered to north-westward as far as Bolong. Thence it passes through Welloo and Kyaukmyo to Kabein. No attempt has been made to trace the limestone band through the trackless forest-covered mountains to the westward.

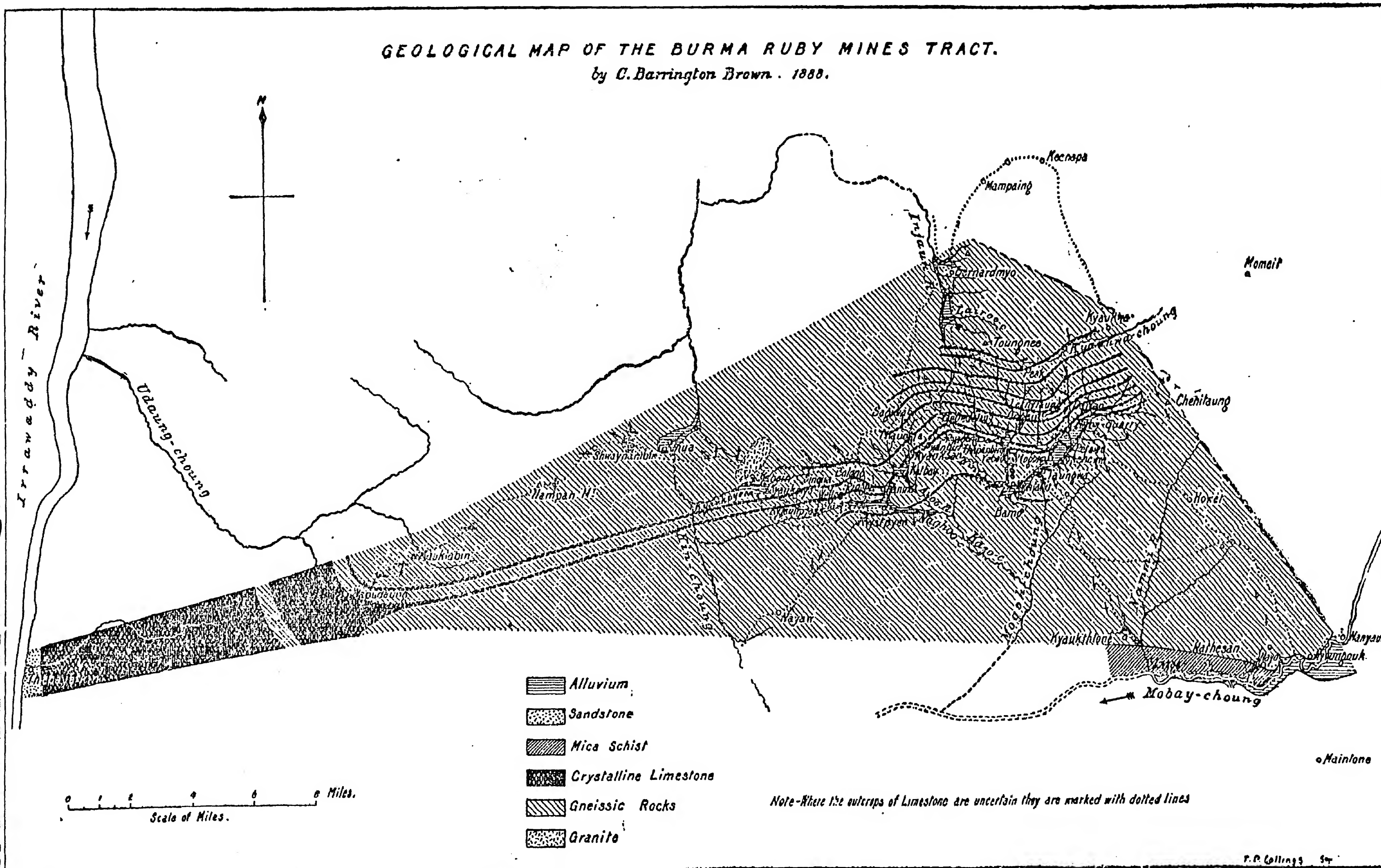
In all cases the limestone bands are conformable in dip to the foliation of the gneissose rocks with which they are associated.

For a distance of four miles, commencing with the small bands at Mogokchoung Falls and ending with that on the peak next below Taungnee, Mr. Barrington Brown estimates the widths of the limestone bands as follows :—

No. 1. 50 feet ; 20 and 30 feet, in two bands, in Mogokchoung Falls.
,, 2. 150 ,, on the north side of Mogôk valley.
,, 3. 300 ,, in two bands of 200 and 100 feet, with 100 feet of gneiss between, on the north edge of Mogôk valley, at the end of Letnytaung spur.
,, 4. 50 feet, on Letnytaung spur.
,, 5. 400 feet in two bands of 300 and 100 feet, with 100 feet of gneiss between, on Letnytaung spur.
,, 6. 250 feet, close to Letnytaung peak.
,, 7. 400 feet, at Letnytaung peak.
,, 8. 50 feet, between Letnytaung peak and that below Taungnee.
,, 9. 300 feet ditto.
,, 10. 700 ,, ditto.
,, 11. 70 ,, in peak next below Taungnee.

The bands, Nos. 2 to 11 inclusive, occupy a distance of 2½ miles, and their collective thickness across their outcrops is about 2,670 feet.

Mr. Barrington Brown found it difficult to obtain good sections showing the junction of the large limestone bands with the main masses of gneiss. Where such observations were found possible, it was seen that near the plane of contact the limestone had a schistose appearance, owing to the contained crystals of whitish and brownish mica being arranged in planes parallel to the foliation of the gneiss. In that part also there appeared to be a greater variety of accessory minerals, such as graphite, white opaque felspar, and violet-coloured spinel. Further away the limestone became more coarsely-crystalline, passing into a sort


GEOLOGICAL MAP OF THE BURMA RUBY MINES TRACT.
by C. Barrington Brown. 1888.
N
Irrawaddy River
Udaung-choung
Mampaing
Kecnapa
Momeit
Kyaukme
Chenitaung
Hokei
Kyaukthinlone
Kathesan
Kanyaung
Mobay-choung
Mainlone
Alluvium
Sandstone
Mica Schist
Crystalline Limestone
Gneissic Rocks
Granite
0 1 2 4 6 8 Miles.
Scale of Miles.
Note—Where the outcrops of Limestone are uncertain they are marked with dotted lines
F. P. Collings Sc.

of white, opaque, or bluish and greyish, semi-transparent calc-spar, in rhombohedra which sometimes attain a size of over six inches across.

The best section of a junction, as well as of one of the main limestone bands, is seen near Pyagone, where the latter (probably No. 3 band) crosses through a ridge from Bobadaung. Here the grey gneiss, of an evenly and finely laminated variety, rests on the limestone, its foliation dipping to the south, like that of the latter rock, at an angle of 45°. Although the plane of contact is clearly defined, yet the gneiss firmly adheres to the limestone. Tracing the section northward it is as follows:—

1. Finely laminated grey gneiss.
2. Crystalline limestone, containing spinel, gneiss, felspar, etc., 18 inches.
3. Finely laminated gneiss, 6 inches.
4. Coarsely crystalline limestone, containing graphite, light-coloured mica, and green crystals of augite, 50 feet.
5. Very coarsely crystalline limestone in irregularly shaped bands, alternating with ordinary crystalline limestone, probably 150 feet.
6. Finely crystalline limestone, containing graphite, mica, and spinel, probably 100 feet.
7. Gneiss underlying the limestone just beyond mine *e*, probably 600 feet.
8. Band of crystalline limestone, probably 150 feet.
9. Gneiss.

This band is again seen cropping out in spurs near Pyanbin on both the east and west sides of the basin-shaped depression at *b* mine. It again appears on the eastern side of Kathay valley, but its greater portion onwards is hidden by alluvium as far as Panma village. From thence onwards it passes through the north-eastern side of Pingu hill, and is seen outcropping through Bolong, Welloo, and Kyaukmyo to Kabein.

Mr. Barrington Brown has also given the details of the extension of other limestone bands, some of which (bands Nos. 4 and 5 on Letnytaung spur) he found to be associated with coarse pegmatite containing large black mica and tourmaline crystals.

In the main set of limestone bands passing through Letnytaung spur, not far from the Momeit road, and one mile north-east of Mogôk, is situated the quarry which was formerly worked for the extraction of rubies from the matrix. The short limestone outcrop there exposed, traced from its southern end northwards, shows some 40 feet of white crystalline limestone, then a wide bed of granular limestone which abuts against a crystalline limestone of a few feet in width, in which are bands of reddish brown mica-crystals, graphite, small crystals of felspar, reddish spinels, and light-green augite. This passes into a coarsely-crystalline, semi-opaque limestone (the matrix of the ruby) of about 20 feet in width; beyond which comes white crystalline limestone extending for some 90 feet. The whole dip slightly to southwards.

The quarry, which is in the coarsely-crystalline, semi-opaque limestone mentioned above, is 20 feet wide at the face, and has been cut

in for 15 feet, to where a small drift in its bottom has been advanced a short distance, making the entire length of the cutting at that part some 30 feet. The rubies are found in the rock over a space of 6 feet in width, extending almost vertically from the bottom of the quarry to the surface of the ground, while the direction of the productive portion slopes to the south at an angle of 70°. On either side of this the rock changes from a bluish-grey to pure white. Along the central line, where the rubies are most numerous, are small developments of a greyish mineral

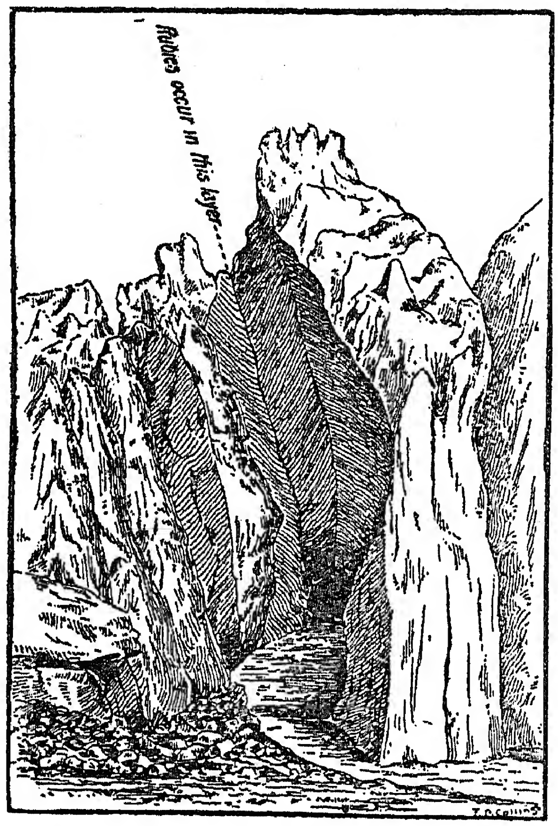


Fig. 5.
Ruby quarry and cave (after C. Barrington Brown).

(diaspore) enclosing small crystals of iron-pyrites, and where these occur the miners assert that the rock is most productive. There is also a small, irregular, vein-like structure of the same mineral traversing this part for a short distance. Besides these there are small, dull-greenish crystals of diaspore, and light-green crystals of augite. In some specimens pyrrhotite was found in contact with rubies.

At the mines close to Bobedaung village there are some fine beds of statuary marble, similar to those seen at the ruby quarry at Mogôk; and here the adjoining crystalline limestone has been quarried for the rubies it contains. This band is evidently the western extension of the one in which the Mogôk quarry is situated. A cave-working near by, called the Royal Loo, was formerly considered to be a very rich one. Between

Thaungla and Pyanbin, in the westward continuation of the same band, rubies have been found in the limestone matrix.

(*b*) *Hill-wash.*

By hill-wash is meant the detrital material not sufficiently removed from its source to permit of perfect sorting of the clays from sands. The richest portions of the hill-wash are composed principally of a dark-brownish, earthy clay resulting from the disintegration of the crystalline limestone. On washing the ruby-bearing materials of this deposit, and eliminating the clay and fine sand, the remaining portion is found to be composed of quartz, gneiss, pegmatite, schorl, garnet, spinel, ruby, and sometimes sapphire.

(*c*) *Alluvium.*

Clays, gravels, and sands form alluvial deposits in the larger valleys of the district. In the upper part of Mogôk valley the alluvium consists of a brown, sandy loam resting upon coarse gravel, beneath which is an admixture of clay, gravel, and sand with rounded blocks of gneiss. In the lowest portion of the gravel and sand rubies and quantities of garnets are found. This rests upon an under-clay, which, in places, is a white floury kaolin containing white mica, the result of the decomposition of the bed rock. The sand grains consist principally of quartz, gneiss, pegmatite, spinel, garnet, tourmaline, rock-crystal, and ruby.

Sapphires of good quality are said to have been obtained in former years from the alluvium of the Injauk Valley, near Bernardmyo (see fig. 6).

Methods of Mining.[1]

The methods of mining for the ruby are suited to the three modes of its occurrence in the limestone, in the hill-wash, and in the alluvium.

Where the ruby-bearing earth is dug out of natural vertical tunnels and caves in the limestone, the excavations are known as *Loodwins*, that is, crooked or twisted mines. The open-cuttings in the hill-wash are called *Hmyaudwins* or water-mines. In the case of the alluvial deposits, where the sands and gravels are in a layer below the level of the river-beds, they are reached by sinking pits called *Twinlones*, or round pits. Formerly these twinlones were made round and of small diameters, but now they are sunk square and of large size.

[1] C. Barrington Brown, *op. cit.*, p. 184.

Loodwins.—The finest and largest rubies are said to have been obtained from the brownish loam, formed by the disintegration of the limestone and infilling the caverns and clefts in that rock. These are

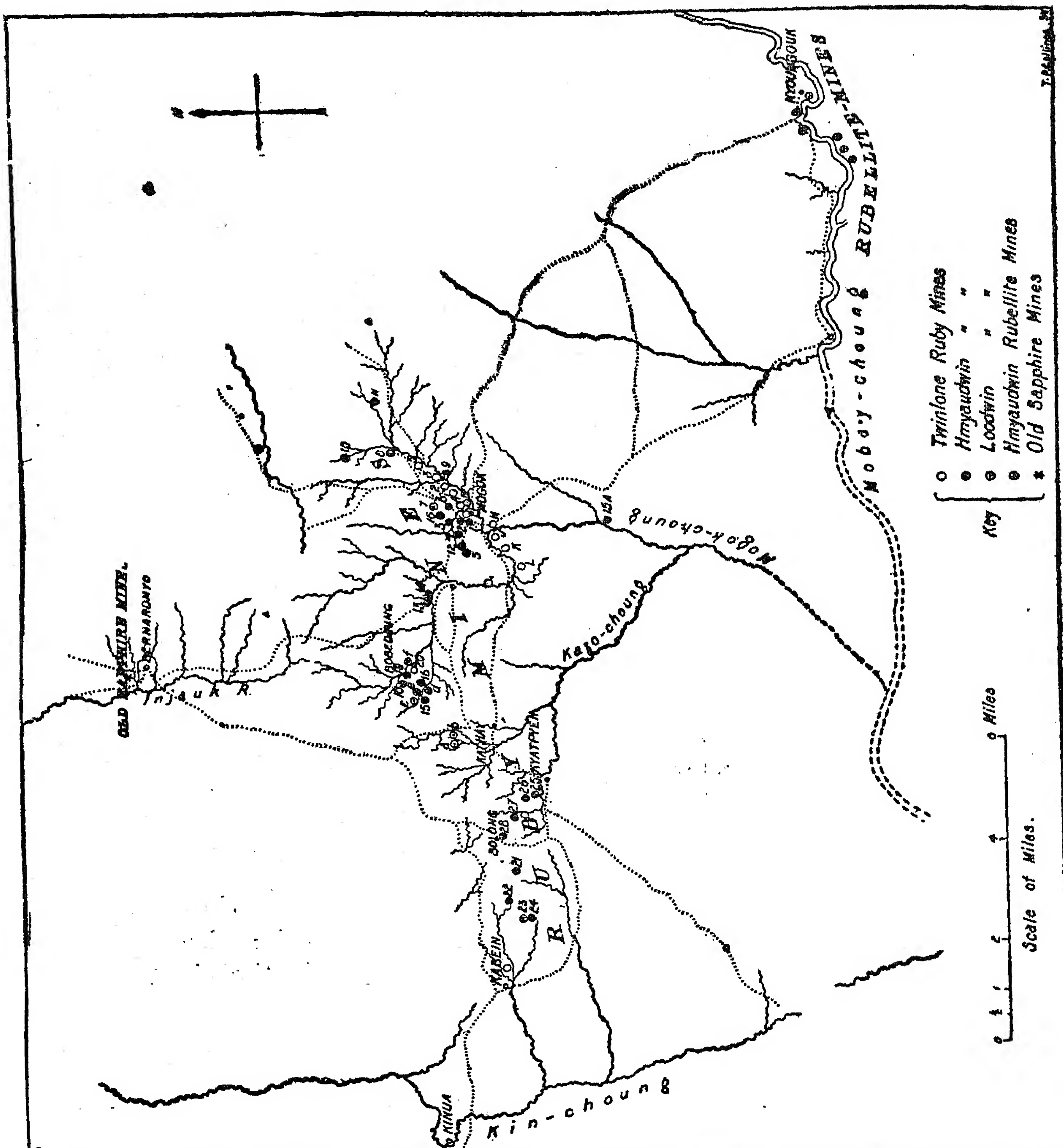


Fig. 6.
Map showing the position of the gem mines in the Mogok area (after C. B. Brown).

often tortuous and irregular in shape, and are sometimes worked by means of perpendicular pits made for the purpose of hoisting up the

material dug out by the miners. The loam is taken to the nearest water-supply and washed in small, flat baskets made of the outer portion of the bamboo with meshes sufficiently close to prevent small mineral fragments from passing through. The Royal Loo is said to have produced a ruby as large as a walnut. In one of the caves rubies were found in association with the bones of a large extinct animal. The exploration of these caves seems to offer the most promising chance of obtaining valuable gem-stones.

The limestone has also been quarried for the rubies occurring *in situ*, but the shocks produced by blasting and subsequent hammering of the rocks invariably injure numbers of the gem-stones.

Hmyaudwins.—The most numerous of all classes of mines are open cuttings of an elongated form, the lower ends of which are open to a hill or gully side. Water is brought, often from considerable distances, to the head of the working, where it is delivered through bamboo poles and flows away through a trench in the bottom of the working, which forms a ground sluice. The water is directed upon the excavated heaps of ruby-bearing stuff, which, when sufficiently softened by the falling water, and cleared of the larger stones, is hauled to the upper end of the sluice and there puddled. When completely freed of clay the mass of mineral fragments is carefully searched for rubies, spinels, etc.

Twinlones are pits sunk in the alluvium. They are now generally made square in plan instead of round, as seen in the old workings in the Kyatpyen valley and elsewhere. They are made from two to nine feet square, timbered, and provided with strong bamboo balance-poles for the purpose of hoisting out the ruby-bearing stuff and the water which accumulates rapidly. As soon as a pit is worked out, which takes from four to ten days according to its size, a new one is commenced near by and the timbering of the old one made use of.

Mr. Barrington Brown is of opinion that with capital and European management improved methods of mining should result in a greatly increased output of precious stones from this area. The great drawback to twinlone mining is the quantity of water in the ruby-bearing gravel, but he thinks it would be a costly matter to drain such valleys as Mogôk, Kathay, Kyatpyen, and Yeboo. Could this, however, be effected in the Mogôk valley, there is still a large quantity of ruby-sand and gravel available. He suggests the employment of adits for draining some of the mines in the limestones.

In February 1888 the number of twinlones and hmyaudwins was 77, employing 771 native miners. No quarry-mines were then in operation owing to the prohibition placed on the use of gunpowder, and some of the loodwins were lying idle for the same reason.

According to the Deputy Commissioner of the Ruby Mines District nine varieties of marketable corundum are distinguished locally by separate names, and their prices vary according to their size roughly as follows:—

	Weight, 1 *rati.*	Weight, 2 *ratis.*	Weight, 3 *ratis.*
No. 1. *Amenyun* . . .	R100—300	R1,000—2,000	R3,000—4,000
" 2. *Anigyi* . . .	40—60	75—150	1,000—1,500
" 3. *Aniswe* . . .	30—50	50—150	300—400
" 4. *Anide* . . .	20—30	40—120	170—250
" 5. *Panye* . . .	5—10	25—30	150—200
" 6. *Asein* . . .	4—30	80—100	150—200
" 7. *Nila*	4—30	80—100	150—200
" 8. *Okthapaya* . . .	½—1½	5—12	30—40
" 9. *Ku-ka* . . .	¼—½	5—7	10—15

Nanyetseik, Bhamo District.

On account of extensive washings for rubies, which had taken place previous to 1894, a "stone-tract" has been declared near Nanyetseik, 32 miles north-west of Mogaung in the Bhamo district, and 22 miles east-south-east of the Jade mines, to the trade of which the village of Nanya owes its existence.

This stone-tract was examined by Dr. H. Warth, late Deputy Superintendent, Geological Survey of India, in April 1895, whose collection of specimens are preserved in the Geological Museum, Calcutta. As in the Ruby-mines district, there is a crystalline limestone, sometimes dolomitic and with numerous accessory minerals, associated with gneiss, granite, pegmatite, and a series of pyroxene-granulites, in which there is often a considerable development of scapolite and calcite. The accessory minerals in this crystalline limestone include augite, pale copper-coloured biotite, spinel, sea-green apatite (moroxite), chondrodite, graphite, scapolite, pyrrhotite, and in one case olivine partially converted into serpentine. These accessories are sometimes so numerous that calcite becomes quite subordinate in quantity. No rubies have been found, so far, *in situ* in the limestone; but they and sapphires have been obtained in the alluvial deposits to the north-west of Nanya, and also near Nokhun

(Lama). Dr. Warth obtained rubies and sapphires by washing the alluvium in this locality at different points over an area of 10 square miles.

Various accounts have been given of the value of the rubies obtained from these mines during the time of King Thebaw; but the stories are too varied and contradictory to be worth recording.

A crystalline limestone similar to that found at Sagyin and Mogôk occurs at Mandalay hill associated also with pyroxene-scapolite granulites, and pegmatite veins.

SAGYIN.

Sagyin is easily accessible from Mandalay, either by road *viâ* Madeya in the dry season or by river *viâ* Sheinmaga. It is situated 21 miles north of the capital in the midst of a range of seven small hills, arranged in a N.—S. line, and isolated by the alluvium of the Irrawaddi plain. The southernmost and highest of these hills, Kamadaung, rising only 808 feet above the level of the sea, is about a mile long and a quarter of a mile wide at its base. The crystalline limestone dips towards the east, giving a gentler angle to the eastern than to the western slopes of the hills. According to Dr. T. Oldham,[1] the limestone rests upon hornblendic gneissose rocks, which form the lower portion of the hills, cropping out on the western steep scarp. Resting on the limestone, and forming a small secondary ridge to the east of it, are beds of a quartzose granular character and quartzites of a bluish tint, sometimes micaceous and felspathic.

The mines have been worked for many years and King Mindoon is said to have obtained R30,000 worth of rubies in one month from an old cave-working and pit in the adjoining alluvium, which were formerly called the Royal Loo.

According to a notification by the Burma Government, dated 6th November 1890, a portion of the Sagyin hills was declared a "stone-tract," and all work except the quarrying of marble was prohibited. The boundaries of the stone-tract are defined as follows:—

North.—A straight line drawn from the north-west bank of the Kangalé tank to the Nawbin tree near Nawbin hill.

East.—Thence from the above tree the cart-track at the foot of the hill to the north gate of the Sagyin north village, where there is a natsin; thence a straight line running east and west to a point where the telegraph line cuts the cemetery; thence the telegraph line up to the place where the cart-track from the foot of the hill and telegraph line divide.

South.—Thence from the point where the cart-track and the line divide the cart-track westerly as far as the kyaung at the foot of the Taungbuza hill; thence a straight line to the southern point of the Kamadaung hill.

1 Yule's Mission to the Court of Ava (1858), p. 326.

West.—Thence from this point a line leaving a clear space of 10 yards along the western ridge of the Kamadaung, Alédaung and Shwesanyindaung hills to a point at the north end of Kandaung bridge; thence a line round the western ridge of the Zeduyin hill to a point where the telegraph line cuts it, and thence the telegraph line to a large tree called Zewa-Kazinbin; thence the cart-track at the foot of the hills to the north-west bank of the Kangalé tank.

According to a report recently made by Mr. H. Hayden, Assistant Superintendent, Geological Survey of India, the rocks of the Sagyin hills may be classified under the four following heads :—

1. Limestone.
2. Gneiss.
3. Conglomerate.
4. Vein-stuff.

The prevailing dip of the limestone-beds is about 40° to E. 12° S. The limestone varies from a pure white rock, in which calcite crystals sometimes measure 3 or 4 inches across, to a bluish-grey crystalline mass. The accessory minerals include yellow mica (phlogopite), chondrodite, biotite, augite, scapolite, pyrrhotite, graphite, orthoclase, spinels, chiefly purple in colour, and rubies.

The gneiss is found chiefly in the southern hills, being exposed on the western slopes of Shwesanyindaung, Alédaung, and Kamadaung, where it is seen underlying the limestone at about one-third of the way up the hillside.

The conglomerate which underlies the gneiss is composed of pebbles of limestone, gneiss, and pyroxene-granulite lying in a calcareous matrix.

The so-called vein-stuff is found filling the interstices and clefts in the limestones, and consists of a red, earthy matrix in which are imbedded the numerous minerals derived from the weathering of the limestone, and is said to contain rubies. A specimen of limestone obtained in one of the old workings by Mr. Barrington Brown contained pale-pink crystals of ruby, with iron-pyrites, and purplish to blue crystals of sapphire.[1]

Both the vein-stuff and the limestone have been worked for rubies. According to Mr. Hayden, the clefts in which the vein-stuff occurs vary from a few inches to four or five feet in width. Where softened by weathering it is dug out and washed in flat baskets by a process resembling that of "panning." The lighter materials are thus removed and only the heavier particles, consisting of small pieces of rock, quartz, tourmaline, spinels, and rubies, remain. The larger fragments of rock, as well as the large lumps of quartz, spinel, etc., are then picked out and discarded, and the remaining minerals are carefully searched through for rubies.

Quarrying has been carried on in the limestone chiefly on the western

[1] *Op. cit.*, page 181.

face of Alédaung, where a broad band of bluish limestone is exposed. This band contains numerous minerals, including mica, pyrrhotite, spinels, and rubies. The spinels are very numerous, being of a pale red colour and occurring in clusters. Unfortunately the quarrying of the limestone, as well as of the hard, unweathered vein-stuff, results in the destruction of numbers of rubies.

The rubies found in the Sagyin "stone-tract" are generally small and violet in tint, although valuable "finds" have been reported. During his examination of this area in December 1895, Mr. Hayden obtained by washing the vein-stuff only about 20 rubies of poor colour, the largest weighing $\frac{3}{8}$ grain. The majority of these came from the eastern slopes between Shwesanyindaung and Alédaung, whilst none were found either on Kamadaung or on Shwesanyindaung. Although the number of stones found in the northern hills was smaller, they were of better colour than those found in the southern hills.

CENTRAL PROVINCES.

According to the *Central Provinces Gazetteer* rubies "were formerly obtained near Wairágarh in the Chanda district, but the mines have long since been abandoned."[1] Sapphires are also said to occur in the neighbourhood of Paluncha, in the Upper Godavari district, but no authority for the statement is quoted.[2]

HYDERABAD.

Dr. A. Walker has recorded that red and white corundum and emery are found in the streams leading from the Kurnigari hills, in the Kummum Circar, and also in the Paluncha country.[3] The white corundum is considered to be the harder and is preferred by the armourers. Dr. Balfour states that there were excellent specimens of irregularly crystalline structure forwarded from Hyderabad to the Madras exhibition.

Corundum is picked up in the fields, especially after rain, as in the case of the Madras occurrences, and from specimens recently sent by the Hyderabad Deccan Company, through the British Resident in Hyderabad, it seems that excellent red and yellow corundum is obtainable in rough crystals showing a set of basal and rhombohedral parting-planes with characteristic "etch" figures. Some of these are deep in colour and almost fit for gems. In one locality (south of Gobugooroo) blue kyanite was found in the same field. The specimens were obtained from north-west of Gobugooroo (lat. 17°17′ N., long. 80°25′ E.), south of Gobugooroo with blue kyanite, Bunjur or old Soorawarum (lat. 17°15′; long. 80°25′)

1 Page 135.
2 Page 506.
3 *Madras Journal of Literature and Science*, Vol. XVI, p. 187 (1851).

and Golagooda or old Toomullapully (lat. 17°15′, long 80°21′). No regular mining for corundum is carried on in the Nizam's dominions; but occasional crystals are picked up by the villagers and sold in the bazars to lapidaries and armourers for use as abrading agents.

KASHMIR.

The existence of sapphires in considerable quantities in some part of the North-West Himalayas became known in India through specimens brought into Simla by traders from Lahol. Some of the specimens were examined by Mr. Mallet in 1882 and found to be sapphires.[1] Various stories are told of the original discovery; according to one of these, which was told to Mr. LaTouche on the spot, a certain shikari having lost the flint of his gun whilst out hunting and in searching for a convenient piece of hard rock to strike a light with, picked up a small sapphire, and finding it served his purpose carried it about with him for some time. Eventually he sold it to a Laholi trader, who took it to Simla, where its worth was recognised. Enquiries led to the discovery of the spot where the shikari had picked up the stone, and further large quantities were brought by the Laholis to Simla, where they were sold for very low prices. According to another story, a number of traders bringing borax from Rupshu arrived in Simla, and whilst emptying their baskets in a merchant's shop found with the borax a stone which they threw into the street. The well-known jeweller, Mr. Jacob, who happened to be passing at the time, so the story says, was struck by the stone. Picking it up, he discovered its real nature and obtained it from the merchant for a very small sum. If there is any truth in this story it points to the occurrence of sapphires also in Rupshu, as the borax, which is brought to Simla, is carried along a route that passes nowhere near the sapphire mines in Pádar. Various other stories about the occurrence of sapphires in portions of the North-West Himalayas are circulated; but none so far have been confirmed.

The sapphire diggings are situated near the village of Soomjam (lat. 33°25′ 30″N., long. 76°28′ 10″E.) on the Bhutna, a tributary of the Chináb entering it from the north-east at Gulabgarh in the district of Pádar. The village of Soomjam is about thirteen marches from Srinagar, at an altitude of about 11,000 feet, and the mines over 13,000 feet, about one mile east of the trigonometrical survey station of Ganar, 14,210 feet. When Mr. LaTouche visited the mines in July 1888 snow was lying on the ground above his camp to a depth of 8 feet, and did not disappear till the end of August, a few small patches lingering on throughout the year.

The small upland valley in which the sapphires are found is about

[1] F. R. Mallet, "On Sapphires recently discovered in the North-West Himalaya," *Rec. Geol. Surv., Ind.*, Vol. XV, p. 138 (1882). T. H. D. LaTouche, "The Sapphire mines of Kashmir," *Rec. Geol. Surv. Ind.*, Vol. XXIII, p. 59 (1890).

1,000 yards long by 400 yards broad at its lower end. The profitable diggings were confined to a narrow patch of *dèbris* about 33 yards wide along the northern side of the valley. Sapphires appear to have been derived originally from a spot high up on the cliff to the north of the valley, near the head of a small ravine which enters it at some distance from the apex.

The sapphire crystals appear to be very local in their development, the only spot where they have been found *in situ* being near the top of the ridge bounding the northern side of the small valley above mentioned, and about 1,600 feet above it, where the face of the rock had been laid bare by a landslip. On the northern side of this ridge Mr. LaTouche found blocks of granite crowded with crystals of corundum, mostly with a bluish tinge, but was unable to find the source of the blocks owing to the enormous depth to which the rocks composing that side of the ridge were weathered.

Large stones have been obtained from this area in past years; one was 5 inches in length and 3 inches in breadth, well coloured in the central portions; but of late years only small sapphires have been obtained.

Mr. LaTouche also found sapphires in a large block of granite lying on the moraine beside the glacier in the Hagshu-lá, one of the passes leading from the Bhutna valley into Zanskar, at an altitude of about 15,500 feet. The block probably came from a point much higher, and perhaps inaccessible; but its source was not discovered during the rapid journey made by Mr. LaTouche into Zanskar.

Rubies of good "water," white sapphire, as well as massive corundum (corundum rock) are reported to have been found with the sapphires of the Zánskar range,[1] whilst the Rev. A. W. Heyde, writing of the sapphires, refers to crystals from the same area which "looked for about an inch like topaz, the colour being that of a deep-coloured sherry wine, quite transparent, the two colours (blue and yellow) running gradually into each other."[2]

MADRAS.

Being the earliest known and the source also of the material used by Count de Bournon in his famous researches, the corundum deposits of the southern presidency command especial interest.

Many occurrences of the mineral in the Salem district and the Mysore State have been recorded by Captain J. T. Newbold, F.R.S., to whom we are indebted for numerous observations made on the Geology of Southern India between 1840 and 1850. Other observers have before and since described various occurrences of the mineral; but it is to the researches

[1] A. G. Young, *Amer. Journ. Sci.*, 3rd Ser., Vol. XXVI, p. 339 (1883). Paper by C. U. Shepard, Senr.

[2] Letter quoted by Mr. Mallet, *Records, Geol. Surv., Ind.*, Vol. XV (1882), p. 141.

of Mr. C. S. Middlemiss, Superintendent, Geological Survey of India, that we are indebted for a precise description of the corundum deposits in the districts of Salem and Coimbatore, and his results are freely quoted in the following pages referring to those localities.

ANANTAPUR DISTRICT.

Samples of corundum were brought to the Geological Survey Office in the year 1880 and were said to have been obtained from the vicinity of Punighi, in the Hindupur talúk. According to Mr. Mallet, who examined the specimens, they were of a sea-green colour, having white felspar and mica attached. The mineral was obtained from pits 6 or 7 feet deep, and it was stated that large quantities had been exported to England. Mr. Hammiell, who brought the specimens, states that corundum is found in several parts of the Madaksira talúk as well as in Hindupur.

On examining the specimens preserved in the Geological Museum, Calcutta, I found the mineral to be in contact with a mixture of magnetite and green spinel (hercynite-pleonaste); so the conditions of this occurrence in Anantapur district resemble those of the Mysore corundum (*see* p. 12).

The Revenue officials have also reported the occurrence of corundum at the following places in this district:—

Motalachintarlapalli, Maddalcheruvu Sivapuram in the Dharmavaram taluk; Nutimadugu, Palavenkatapuram, Manirevu and Obalapuram in the Kalyandrug taluk; Danduvarapally, Pasulur, Siddarampuram, Reddipally Atmakur, Paramatiyelaru, and Thimmapuram in the Anantapur taluk.

COIMBATORE DISTRICT.

In this district corundum has been found at the following centres:—

(1) *Selangapalaiyam*, Bhaváni talúk.
(2) *Gopichettipalaiyam.*
(3) *Karutapalaiyam.*

Corundum is also reported from *Padyur*, *Shigrispalaiyam*, *Kandyankovil*, and *Kangyam* (*Karutapalaiyam*) where it occurs as large idiomorphic crystals several inches across in oligoclase.

(1).—*Selangapalaiyam.*

Corundum has not been found *in situ* in this area. It occurs scattered in irregular, rolled lumps, varying in size from ¼ inch to 1 and 2 inches across, in a field extending from near Chinnanaykkanur to Selangapalaiyam. The rocks of the neighbourhood appear from the few poor exposures to be a muscovite-biotite gneiss with wavy foliation, and with

veins of a coarse-grained, pink, graphic granite penetrating it irregularly. The village *karnam* informed Mr. Middlemiss that it was not gathered systematically, but picked up from the fields chiefly by women during the rains, perhaps to the extent of 25 to 30 maunds annually.

(2).—*Gopichettipalaiyam.*

The corundum is found according to the Revenue Inspector in one field only, No. 94, which is owned by the village magistrate and situated about half-a-mile north of the travellers' bungalow. Mr. Middlemiss says there was a fairly large quantity scattered over the field at the time of his visit, pieces about the size of walnuts being fairly numerous. It appears that a contractor came from Madras annually and took away all the corundum procurable; that he employed 30 or 40 cooly women, who, working for about three months in 1894, collected two large cart-loads. Each woman could collect from about ½ to 1 Madras measure (= R80 weight) every day.

(3).—*Karutapalaiyum.*

Between the village of Karutapalaiyam and the temple-crowned hill of Sivamalai, which lies about two miles to the east-south-east, there stretches a row of six or seven small rocky hillocks composed of the same rock as the hill itself; they are in fact structurally a west-north-west continuation of the Sivamalai mass.

Two rocks of different composition and structure are connected with the appearance of corundum at this place. The one is the pale grey elæolite-syenite of the Sivamalai hill, and the other a coarse felspar-rock intruded as veins into the former rock.

The former is composed almost wholly of elæolite, anorthoclase, plagioclase, hornblende, biotite, augite, calcite, graphite and iron-ores, forming a medium-grained rock with a granulitic structure. Through the common, medium-grained type coarse "contemporaneous" veins ramify, with crystals of elæolite measuring sometimes five inches across. The whole rock weathers into large pale ochre-coloured blocks forming small tors.

Along the northern foot of these hillocks, between Karutapalaiyam and the Tiruppur-Kangyam road and extending for a distance of one mile, there are a series of holes and trenches made by the owners of the lands, which reveal the coarse felspar rock alluded to above. It is a dark-red, white, and black non-foliated rock, composed of red or deep flesh-coloured felspar, which is a form of plagioclase, and biotite in large nests of small plates.

It is in this extremely coarse, red felspar rock that the corundum is found as large, well-preserved, six-sided crystals of a dark or light greenish-grey colour. The mineral appears in this completely unaltered rock as if it were a normal mineralogical constituent. It possesses no shell of any other mineral as in the case of the Sittampundi occurrence and other localities where the corundum is found in its matrix. There is nothing to suggest in this case that the corundum was formed subsequently to the matrix in which it lies; nothing to suggest a secondary origin for it.

At the time of Mr. Middlemiss' visit (1895) the mining or digging out of the corundum near Karutapalaiyam was quite an active industry on a small scale. The fields on the northern side of the row of rocky hillocks of waste-land had been taken up, not for the purpose of cultivation, but for corundum mining. There are a number of irregular holes and some few regular trenches, the latter following W. by N.—E. by S. (the direction of strike of the roughly foliated syenites) or at right angles to this direction. One of these was 30 yards long, 2 yards wide, and 20 feet deep. Another trench was dug along a direction N. E. by E. for 15 yards. It was 20 feet deep and 2 yards wide, and it followed the junction of the two rocks mentioned above. The largest and most productive working was close to the village of Karutapalaiyam. Here were obtained some very large crystals of corundum 6—8 inches across. A basketful of the mineral weighing about 14 seers (28lbs.) was gathered during a day of eight hours by four men, their wives, and little children.

A past generation are reported to have made a very good thing out of the corundum of this place, when the stuff sold for R40 per podi=192 Madras measures.

This locality Mr. Middlemiss considered to be the most promising amongst those he had visited in the Coimbatore district.

KISTNA AND GODAVARI DISTRICTS.

Corundum is said to be found in the crystalline rocks of Nellore and Guntur; and where the Godavari escapes through the Eastern Ghâts, east of Papconda, from the Nizam's dominions to the plains of Rajahmahendri and the sea.[1] Specimens from Kodur Guntur and the hills north-west of Rajahmahendri are exhibited in the Madras Museum.

Samples of corundum from Guntur were exhibited at the Madras exhibition by Mr. Rohde and considered by him to be suitable for jewellery.[2]

NORTH ARCOT DISTRICT.

According to Dr. Heyne emery is found at Bombardipádu, about

[1] Newbold, *Journ. Roy. As. Soc.*, Vol. VIII, p. 153 (1844).

[2] *Selections from Records, Govt. of Madras*, No. XXXIX, p. 90 (1857).

20 miles north of Tripaty (? Tirupati), in hornblende-rock, in pieces varying from the size of a pea to that of a hen's egg or even larger[1]; but the frequency with which hercynite has been mistaken for emery makes a confirmation of this determination desirable.

SALEM DISTRICT.

Mr. Middlemiss has reported on the corundum deposits of the following places:—

(1) *Sithampundi* or Sittampundi, near Solasiramani (Sholasigamani), Námakkal taluk.
(2) *Paparapatti* and neigbourhood, Dharmapuri taluk.
(3) *Rengopuram*, Dharmapuri taluk.
(4) *Road from Dharmapuri to Morappur.*
(5) *Royakotta*, Hosur talúk, a probable extension northwards of the Paparapatti deposits (No. 2).[2]

(1) *Sithampundi area.*

This area is interesting because the association of minerals with the corundum is very strikingly like those described in the original paper by Count de Bournon and stated to be obtained in the Carnatic.[3] The place was also reported on by Captain Newbold in 1842. It lies a little east of the river Cauvery, and five miles south of the boundary dividing the Tiruchengodu talúk from the Námakkal talúk. The productive area lies south-west, south, and south-east of Sittampundi village, occupying a slightly elevated bit of rising ground running with its long axis west-north-west and east-south-east at a distance of from one mile to half-a-mile from the village, and traceable, according to Middlemiss, for a distance of about two miles, varying in width from 100 to 1,000 yards.

The rocks to the north of the corundum area consist generally of a great series of biotite gneissic rocks, covering large areas, and with bosses and veins of a coarse, reddish granite bursting through them and often forming picturesque crags and precipitous hills, such as that at Tiruchengodu town, and the similar hills in the vicinity.

But the actual rock present at the corundum workings differs from the above in being a gneissic rock of a pale silvery or pearly grey colour, streaked with black, and consisting of anorthite (indianite) and hornblende, chiefly, with accessory minerals like garnet, and minute quantities of chondrodite (?).[4] In structure the rock is a crystalline granular aggregate of anorthite, with rather elongated prisms of hornblende, sparsely or numerously arranged with their long axes roughly parallel to the foliation.

1 Heyne's Tracts on India (1814), p. 110.
2 Middlemiss, *Rec., Geol. Surv., Ind.*, Vol. XXX (1897), p. 118.
3 *Phil. Trans.* (1802), p. 233.
4 Probably the mineral described by Lacroix as *fouquéite* (*Rec., Geol. Surv., Ind.*, Vol. XXIV, p. 186 (1891).

The rock is well foliated in bands which generally run perfectly straight, and which differ in the relative amounts of the pale mineral (anorthite) and of the dark mineral (hornblende) present. In some places the hornblende, in others the anorthite, make up nearly the whole rock. Garnets also become locally very numerous. The specific gravity of a specimen with but little hornblende and garnet was found to be 2·824.

It is among this gneiss that the corundum appears, dotted about at random among it like porphyritic crystals of orthoclase in a granite. The mineralogical composition, structure, and general appearance of the rock-matrix here is plainly the same as that recorded by Count de Bournon and named "Indianite" by him. The microscopical examination of the two rocks shows them to be practically identical.

In some sort of association with the anorthite-gneiss, which is n ot disclosed by any exposures on the ground, there must occur a very coarse binary granite consisting of quartz and pink or flesh-coloured orthoclase-felspar, inasmuch as large pieces of the latter, and beautifully clear, smaller fragments of the former are found scattered over the ground in perfectly fresh lumps and showing no trace of rolling by the action of water.

On each side of the *in situ* gneiss, which forms the rising ground, there are gentle slopes of the same rocks, partly or wholly buried under surface material formed of the broken-up gneiss and with here and there a recent calcareous pisolitic tufa, derived no doubt from the decomposition of the lime felspar (anorthite).

The corundum occurs in two ways in the area:—

(1) In the bed-rocks as described above.

(2) In the gentle slope of *dèbris* along with the weathered pieces of the bed-rock.

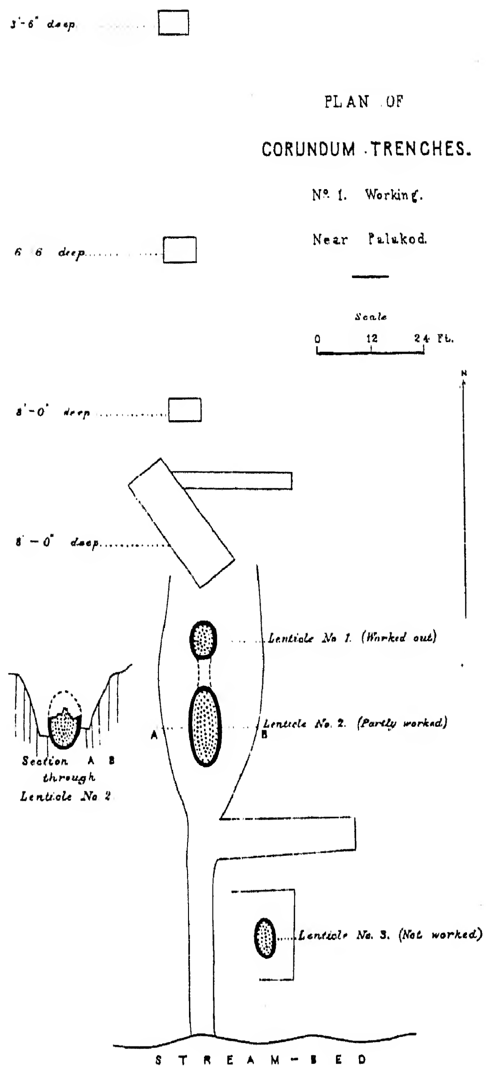
It is of a pale, greenish-grey, rarely flesh colour, and occurs sparsely distributed among the parts of the gneiss which are richer in anorthite. It takes the form of irregular lumps averaging from one-quarter to one inch in diameter. The crystals do not, as a rule, show the prismatic and pyramidal faces, though some specimens from this locality in the Survey Museum are in the form of short, six-sided prisms characteristic of corundum. They exhibit, however, rhombohedral parting-planes which may be detected as fine and very regular lines crossing one another at an angle of about 95 degrees, and ruled, as it were, at fairly regular intervals. These fine lines crossing one another in this distinct way are a good practical distinction in the field between this mineral and pieces of orthoclase, or other felspar, especially in the case of the flesh-coloured corundum, which at first sight may be easily confounded with the flesh-coloured felspar referred to in a previous paragraph.

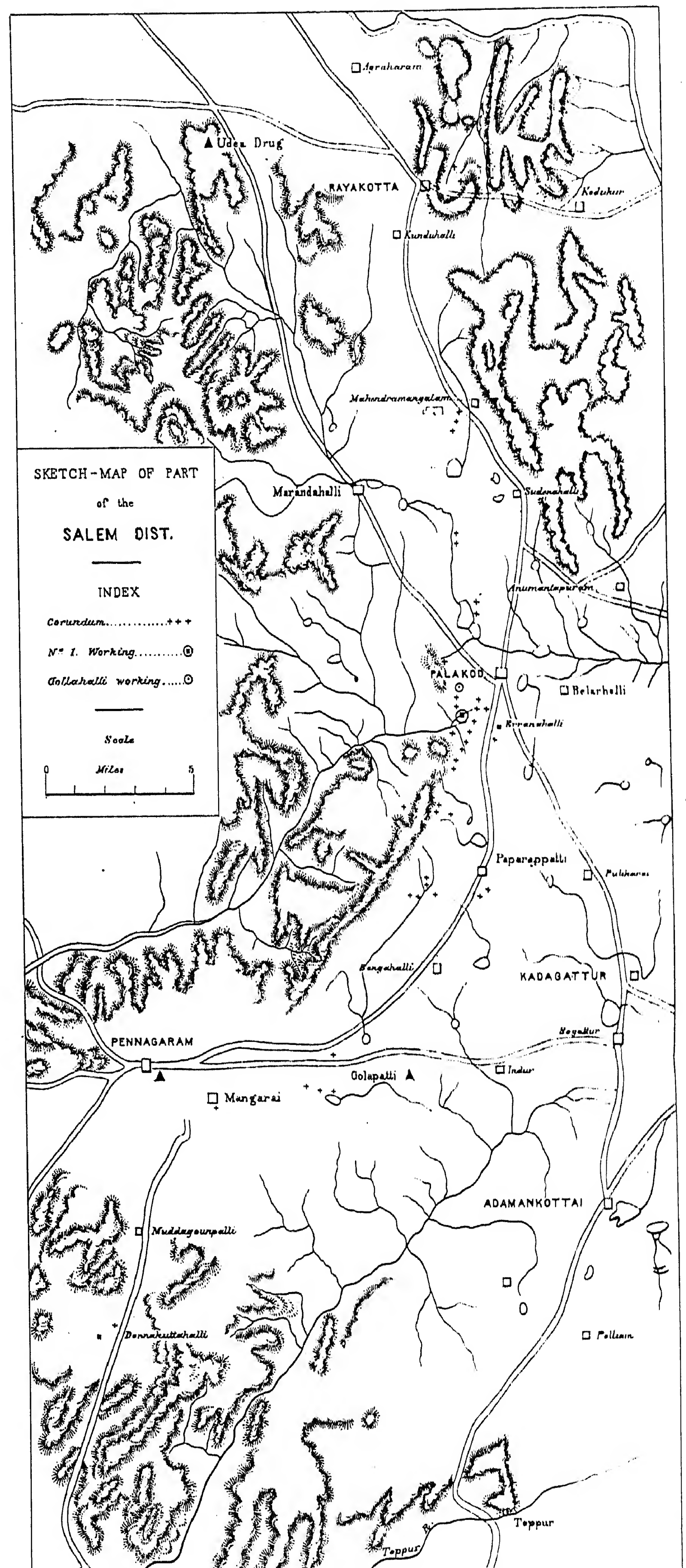
Nearly all these pieces of the mineral are surrounded by a shell of calcite from one-fourth to one-eighth inch thick, in which they lie among the matrix.

T. H. Holland.

ECONOMIC GEOLOGY–CORUNDUM.

Map No 4





The corundum found in the *dèbris* slopes is the same as that of the matrix rock, inasmuch as the former is simply derived from the latter by weathering.

Besides the grey corundum noted above, and the flesh-coloured variety into which it passes, there are to be found fragments, generally minute, of red corundum, which very locally pass into ruby. The brighter coloured pieces of these, which are but seldom larger than one-fourth of an inch in diameter, were found by Middlemiss only in the more hornblendic layers of the gneiss; and they lie in it surrounded by a shell of anorthite partly converted into calcite. These pieces are not generally transparent, but dull and opaque, and of a red-currant colour. But here and there minute points of a fairly translucent red colour may be detected, and there is little doubt that occasionally rubies of value have been extracted from these rocks, as is reported traditionally and by Newbold (*Journal, Royal Asiatic Society*, Vol. VII, page 224). The grey and the flesh-coloured corundums are found all over the area to the south-west, south, and south-east of Sittampundi.

2.—*Paparapatti area.*

Paparapatti lies ten miles north-west of Dharmapuri in the taluk of that name. The area productive of corundum lies to the west-north-west of the village in a cultivated alluvial plain stretching up to a small range of rugged hills, and in which the rocks crop out at irregular intervals. On the tracing from the quarter-inch map forming Map No. 3, Mr. Middlemiss has marked with crosses the places where corundum has been actually seen and found by him, although the productive patches are probably more numerous than here represented.

The rocks of this neighbourhood are members of the charnockite series ("biotite-gneiss" of Middlemiss). They are often well-foliated, with a foliation-strike approximately N. N. E.—W. S. W., that is to say, agreeing with the general trend of the hill range to the west of Paparapatti. Veins of a very coarse granite with red felspar and clear white quartz penetrate the charnockite series, as well as veins of a closer-textured purplish granite. There are other intrusive veins of dark compact trap.

The actual matrix of the corundum in this area occurs as bands of lenticular masses of principally deep flesh-coloured orthoclase (finely crystalline, and showing under the microscope a fine microperthitic or cryptoperthitic intergrowth of possibly plagioclase), in which there is often a considerable proportion of sillimanite (fibrolite), rutile, opaque-black and green spinel, with biotite, which last is especially developed at the periphery of each lenticle (*supra*, p. 18).

The size of these lenticles is sometimes as much as fifteen feet long and eight feet across where actually seen in the rock.

The corundum here differs entirely in appearance from that of Sittampundi. It is of a deep purplish-brown or sometimes dark greenish-grey colour, and it is always regularly crystallised into hexagonal prisms with a great number of variously-inclined pyramidal faces imperfectly developed, and so giving the prism an elongated barrel, or even spindle shape.

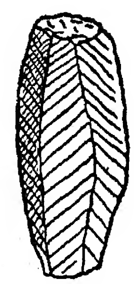


Fig. 7. Crystal of corundum showing the curved faces due to alternation of the prism and pyramid, as well as traces of the rhombohedral parting planes. Paparapatti area, Salem district (*natural size*).

In size they vary from extremely minute grains and crystals, only visible in a microscopic section, to large crystals, several inches long and from one-fourth to one inch in diameter. The characteristic parting planes parallel to the rhombohedron are easily made manifest by breaking the crystals and sometimes traces of these planes are visible on the prism faces (fig. 7). Occasionally also a combination of the rhombohedron and prism may be seen in a single crystal. Each crystal is surrounded by a shell of purer orthoclase, generally flesh-coloured, but sometimes white, having a thickness of from one-fourth to one-eighth inch. When a corundum crystal has been broken out or has dropped out from the rock, the place where it lay can always be distinctly recognised by this shell which remains behind. Microscopic examination shows that this shell differs from the remainder of the matrix in the absence of minute corundums sillimanite and most of the accessory minerals.

It is clear from the map that the outcrops of the rock in which corundum occurs lie in successive lines, roughly parallel to the strike of the gneiss, namely, N.N.E.—S.S.W.

This conclusion has since been confirmed by the discovery of corundum occurring under precisely similar geological conditions in the Hosur taluk to the north (*infra*, p. 43), and also in the same line to the south, making the corundum-bearing band over 24 miles long. This fact and the circumstance that the mineral occurs in two and probably more parallel bands of slightly different rocks, make the Paparapatti area a decidedly promising one. Experiments, to test the prospects of mining for corundum along this band, have been conducted by Mr. C. S. Middlemiss on a lenticle measuring $13 \times 8 \times 9$ feet, near the village of Erranhalli, $2\frac{1}{2}$ miles

S.W. by S. of Palakod. It was found that 722 cwts. of matrix-rock yielded 2,845lbs., or nearly 3·5 per cent. of pure corundum, at a cost of R385-2-0, that is, at 8 annas per cwt. of rock broken up and 3·9lbs. of corundum cleaned. As the chief expense was incurred by the mere labour of crushing the rock, which was done entirely by hand, it is certain that the cost of extracting the corundum would be greatly reduced if stone crushing and washing machinery had been employed, as of course would be the case in actual mining operations on a large scale.

(3) *Rengopuram.*

The corundum of this area is found on the outskirts of the forest land near Pennagaram, two miles north by east of Rengopuram village in the Dharmapuri taluk. Here, according to Mr. Middlemiss, there are two pits sunk through a rock composed of alternate layers of a felspathic rock and a hornblende-gneiss. Although no corundum was found in the rock itself the mineral occurred abundantly in the surface débris overlying the edges of the mine, and possibly may have been derived from a more distant point by movement of the soil-cap down the slope; but no satisfactory explanation could be obtained for the mine which had been carried down some distance into the bed rock.

The corundum here occurred generally in short hexagonal prisms, greenish grey in colour and very much rounded and water-worn into holes—facts confirming the suggestion that they came from some distance.

(4) *Road from Dharmapuri to Morappur, near 6th milestone.*

Near this point there are two corundum-producing areas. At the first place, which lies at the foot of a low hill a little west of the foot-path, one mile south of the milestone, the rock and mode of occurrence of the corundum entirely resemble those of the Paparapatti area. The exposures show signs of having been worked within a radius of a few yards. Mr. Middlemiss did not succeed in finding any further exposures of the same rock in this neighbourhood.

At the second locality, which is two miles north of the milestone, no good exposure of the rock was found; but the few fragments found in a field showed the corundum to be of a dark-grey colour, set in a very fine-grained rock, resembling a phyllite or schist.

(5) *Royakotta, Hosur taluk.*

The rocks in this locality resemble those of the Paparapatti and Palakod area in the Dharmapuri taluk to the south (*vide* p. 41) and several new corundum-bearing localities have been discovered by Mr. Middlemiss along a roughly N.—S. line from about 1 mile E. of Royakotta, along the

same belt of rocks towards Palakod, in the neighbourhood of Jaggasamuddram, and for some miles further south.[1]

SOUTH KANARA DISTRICT.

Specimens of corundum obtained from Kemmar village, Uppinangadi taluk are exhibited in the Madras Museum. Although nothing is known of the rocks in which this corundum occurs, their position suggest a continuation in the N.N.W. direction of the corundum deposits of Mysore, where the rocks are foliated along a line running N.N.W.—S.S.E., and corundum has been found at several places along this line for quite 30 miles. The Revenue officers report that corundum has also been found at Bandar, Kadicar, Hirebandady, Ellenir and Malekai in the Uppinangadi taluk.

MYSORE.

The earliest description of the occurrence of corundum in Mysore appears to be by Lieutenant Newbold,[2] who described the mines of Golhushully, in the division of Noogyhully and Kulkairi in the division of Chinrayapatam, about 7 or 8 miles east by north of the Fort of Gram, and about 98 miles west of Bangalore. The corundum occurs with schorl in a bed of talcose schist associated with mica-schist, gneiss and protogine (? pegmatite). The mineral was extracted from shallow pits and separated by the miners into four classes, namely the reddish brown, white chips of both colours, and refuse. The first three were, according to Newbold's informants, sent down the ghâts to the ports of Mangalore and Tellicherry, where they were sold to Bombay and Arab merchants at prices varying from R12 to R30 per *candy*[3] according to quality. The mines were stated to have been opened about the year 1830. Newbold was also informed that corundum occurred at Burkunhully, Kundeo and Yedgunkul in the Chinrayapatam division; at Norhik in that of Narsipur, at Deysani Kurbonhalli in that of Baunawaram, at Appianhalli in the division of Harnully, Beygoor, Bunnercota, and Mundium, in the Astagram division. Dr. Balfour adds from specimens in the Madras Museum, Nullapardy on the road to Bangalore, Cuddoor, and Nuggur in the Nuggur division.[4]

The corundum occurrences of the *Hunsur taluk* which were cursorily examined by the author in 1892, are associated with graphitic schists, hornblende-felspar rocks, amphibolites and fibrolite rock. They follow the general north-north-west and south-south-east strike of the crystalline schists, and are traceable at intervals from Singanamaranhalli on the south-east to Ramanhalli on the north-west. At Singanamaranhalli the masses

[1] *Surv., Ind.*, Vol. XXX, p. 118.

[2] *Madras Journ. Lit. Sci.*, Vol. XI, p. 46 (1840); also *Journ., Roy. As. Soc.*, Vol. VII, p. 219 (1842).

[3] About 500 lbs.

[4] *Sel. Rec., Madras Govt.*, No. XXXIX, p. 92 (1857).

of corundum adjoin a great intrusion of basic and ultra-basic rocks of a remarkable nature. Some of these, the olivine-bearing types which resemble the dunite and its associates in the Chalk hills of Salem district, are much decomposed and veined with magnesite, chalcedony and serpentine. Associated with these are rocks made up almost entirely of granular hypersthene, magnetic iron-ore and hercynite, a green iron-alumina spinel. The significance of this association has already been pointed out (*ante*, p. 12, *et seq.*) It is not improbable that the rocks in which the corundum occurs in this taluk form part of a structural extension of those containing the corundum deposits of the Uppinangadi taluk, in South Kanara district. The fresh portions of the rock are seen to be composed almost entirely of corundum crystals, but the mineral is commonly decomposed with the formation of a soft hydrous mineral resembling pinite, and with the decomposition products at Nadappanhalli large quantities of graphite and chloritic minerals occur.[1]

For the following list of occurrences in South Mysore I am indebted to Dr. J. W. Evans. LL. B., Director of the Mysore Geological Department.

Survey Map No. 50 N. S. (O. S. 52).[2]

Râmnâtpur (on the River Kaveri).—About 2 miles to the south along the Periyâpatna road, and further to the south on the east of the road many fragments of dark grey corundum are found.

Survey Map Sheet No. 51 N. S. (O. S. 53).

Nadappanhalli (7 miles south-west of Bilikere).—On the cart track north-west of the village is a large pit 16 to 17 feet deep, where corundum is systematically worked. The mineral is dark-grey and is imbedded in a matrix of crystals of the same color that are easily scratched with a knife; this rock occurs in rounded masses. The surrounding rock is of a brick-red color; it appears to be a much decomposed talc schist. To the north a little south of the village of *Hospur*, red corundum is found in scattered crystals.

Bannikuppé (about half a mile south of the Bilikere-Hunsur road, seven miles west of Bilikere).—South of a tank near the village, irregular fragments of corundum occur on the surface. It is pale in colour and apparently free from impurities.

Hunsur (3 miles to the west of the town).—A few crystals of corundum are found north of the road near milestone 112.

Vaddarhosali (about four miles south of Bilikere).—At various points in a line north-north-east from the village, corundum is found *in situ*. Small crystals occur in a matrix of dark-grey mineral easily scratched

[1] *Cf.* Judd, *Min. Mag.*, Vol. XI, p. 59 (1895).

[2] Standard Sheets 1 in.=1 mile, Mysore Trigonometrical Survey.

with a knife. The corundum, as a general rule, forms only a portion of the rock; in places agglomerations of large crystals occur with a soft glistening matrix.

Survey Map, Sheet No. 52 N. S. (O. S. 54).

Dharmapur (11 miles north-north-east of Heggadevankote).—South of the village a few scattered pieces of corundum are found on the surface.

Tarvalli (6 miles south-east of Heggadevankote).—Massive, reddish corundum is obtained from a pit on the northern slope of the hill marked 2,517. It seems to occur in an irregular vein one or two feet wide, between decomposed fissile gneiss on the east and a green decomposed talcose rock containing mica on the west.

Survey Map, Sheet No. 77 N. S. (O. S. 56).

Basárálu (about 13 miles north-north-east of Mandya).—Loose fragments of corundum occur from one to two-and-half miles to the north of the village.

Sátnur (about two miles north of Mandya).—Loose fragments of corundum occur south-east of the temple, below the dam of the tank.

Yerahalli (about half a mile north-west of Yaliyur station and five miles west of Mandya).—Loose fragments of corundum occur between this village and Averhalli to the westward.

Tavasanhalli (about 3 miles west of Mandya).—Loose fragments of corundum occur about a mile west of the village and also to the east of the village, and again further to the north-east near Konhalli.

Kiragandur (about two miles south-west of Mandya).—Loose fragments of corundum occur between this place and Kalhalli on the Mandya-Seringâpatam road.

Rámanhalli (about two miles south of Mandya).—Scattered crystals of corundum occur to the west of the village near the hill marked 2286.

Survey Map, Sheet No. 78. N. S. (O. S. 57).

Budi Hoskote (about a mile south of the Kaveri river near the confluence of the Lokshmantirtha river). Scattered crystals of gray corundum are found on the surface south of the village. Lumps occur in which the crystals are imbedded in a matrix of a white decomposed material.

Bommanhalli (about three miles south of Yelwal). At two points, one-half and three-fourths of a mile, respectively, to the east of the village, large crystals of deep-red corundum and smaller purplish crystals are found on the surface; to the east-south-east and about half-a-mile west from Hemmanhalli, similar corundum is found on the surface; about half-a-mile south-west of Bommanhalli village corundum is found *in situ*. In the northern part of this deposit small crystals occur in a gray granular matrix.

To the south deep-red crystals occur in a fissile, highly micaceous gneiss. They are associated with a soft, olive-green material, which usually envelopes this corundum. In some places this material and the corundum constitute about one-third of the rock. About half-a-mile further to the south, at a point south-east of *Manikpur*, dark-gray corundum is found in a pale, greenish, steatite-like matrix.

Nughalli (nearly three miles south of Bommanhalli).—North-west of the village corundum is found *in situ*. A few crystals of black corundum occur in a granitoid mass of black and grey-brown crystals of a steatite-like material. Near the hill marked 2,796 loose fragments of reddish corundum are found associated with garnets.

Sargur (about five miles south-south-west of Bommanhalli).—Half a-mile west of the village scattered fragments of red, light, and dark-grey corundum are found. A little further west, and west of a village named Golanbid, which is omitted from the map, fine crystals of green corundum occur on the surface of the fields. A few reddish and black specimens are also found.

Mariyanhundi (about three miles south-west of Bommanhalli).—Scattered fragments of irregular crystals of a dark-blue corundum are found on the surface.

Ankanhalli (about four miles from Yelwal on the Yelwal-Hunsur road).—A few fragments of red and grey crystals are found on the surface east of the village.

Yelchodi (south of Bilikere tank, about six miles west of Yelwal on the Yelwal-Hunsur road).—Fragments of deep red corundum are found about half-a-mile east of the village.

Chik Bechanhalli (about one and a half miles south of Yelchodi).—Grey corundum in a matrix of grey crystals easily scratched with a knife is found about two miles south of the village. A pale green mineral considered by the natives to be corundum, but which is easily scratched with a knife, occurs in a white felspathic matrix west of the village.

Kupya (about four and half miles south-west of Bannur).—On the small ridge about a mile north-east of the village many small red crystals of corundum are found on the surface. On digging a trench it was found *in situ* in a highly micaceous gneiss. Each crystal is surrounded by an envelope of a pale, pinite-like material. To the southward large crystals of pale corundum are found on the surface.

Butgahalli (about two and a half miles north of Bannur).—Pale pink corundum occurs a little north-west of the village.

Madgahalli (about two miles from Bannur near the Seringapatam road).—Pale grey corundum is found in an iron-stone hill marked 2,319, south-west of the road.

Shenapathalli (about two miles south of Bannur).—A few crystals of red corundum are found west of the village.

Basvanhalli (about two and a half miles from Bannur on the Malvalli road).—Dark corundum occurs on the north-east of the village.

Sannakikoppal (about four and a half miles from Bannur on the Malvalli road).—Loose fragments of corundum occur on the surface north-east of the village. Ceveral pits were dug just north of Sannakikoppal. In these the mineral was found *in situ*, sometimes in separate crystals, sometimes in massive aggregates of crystals up to nine inches in diameter. It forms a very irregular vein. The immediate matrix is a soft, white, friable, decomposed material. In one pit the corundum was closely associated with a porphyry dyke; in another it was accompanied by patches of quartz, chlorite, and black mica irregularly distributed and apparently of secondary origin. The rock appears to have been originally hornblendic gneiss.

Kempegoadkoppal (about a mile east of Yachenhalli on the Mandya-Bannur road).—A few crystals occur south of the village and also a mile further to the south-east just to the west of Nughallikoppal.

Taghalli (about four and a half miles east of Bevinhalli on the Mandya-Bannur road and about three and a half miles south-east of Mandya).—Loose crystals of corundum occur about half-a-mile south-west of the village, also east-south-east of Malligere and north-east of the tank near Pura.

Survey Map, Sheet No. 79 N. S. (O. S. 58).

Chattanhalli (about thirteen miles from Mysore on the Mysore-Antarsante road).—Corundum occurs *in situ* south-west of the village, just north of the temple, near the level 2,371. Small dark crystals occur in a soft white matrix; loose crystals are also found to the north-west between Mavinhalli and the height 2,963.

Kaniyanhundi-Hosur (nearly a mile south of the village).—Grey corundum occurs *in situ* in a matrix of softer grey crystals. Fragments of purple corundum also occur on the surface to the south-west at a point a little north of Hosur, a village the site of which appears on the map, but not the name.

Survey Map, Sheet No. 108 N. S. (O. S. 60).

Gurdevarhalli (about five miles south of Maddur and one mile east of the Maddur-Malvalli road).—Fairly large corundum crystals occur in the ferruginous gravel north-west of the village.

Tippur (about seven miles south-east of Maddur).—Large crystals of corundum are said to occur near the hill 2,531, north-east of the village.

Survey Map, Sheet No. 109 N. S. (O. S. 61).

Arasinkere (west-south-west of level 2,042 on the Maddur-Malvalli road, eight miles north of Malvalli.—It is the small village south of the

tank, not the large one to the north shown in sheet No. 108). Two corundum pits have been excavated east-south-east of the village, about a quarter of a mile east of the Police station on the Maddur-Malvalli road. Other pits occur to the south. Each particular outcrop of corundum appears to run north and south, but the mineral is said to extend in an east and west direction from Tippur, Sheet No. 108 N. S., on the east, to the deposits near Taghalli, Sheet No. 78, on the west

Nelimakanhalli (a little east of the Maddur-Malvalli road, about three miles from Malvalli).—Loose fragments of corundum occur on the surface a little west of the village. On digging, a thin irregular vein containing small dark crystals of corundum in a matrix of pale decomposed, more or less calcareous, rock was found.

Bugathalli (just west of the Maddur-Malvalli road, about one and a half miles from Malvalli).—Scattered fragments of small crystals are found a little north-west of the village.

PUNJAB.

Mr. J. Calvert[1] is said to have found " sapphires worth R2,500 each, besides other gems " in the Upper Raini valley, near the headwaters of the Beas, below the Hamta pass, in Kulu; but the discovery has not since been confirmed. The same author[2] speaks of rubies in Kulu, but does not give the locality.

REWAH.

The first mention of the Rewah corundum deposits is contained in a paper by Dr. Francis (Buchanan) Hamilton.[3] He was, however, unable to visit the locality itself, but obtained his information at Mirzapur in the year 1814. There was apparently a considerable trade in the mineral at that time.

According to Captain W. S. Sherwill,[4] who was also unable to visit the actual locality, the mines were worked only once a year (in 1845) when enough was obtained to supply the wants of the *mahajans* (merchants), who took the mineral away on bullocks and supplied the greater part of Western India. The following varieties were represented by specimens sent by him to the Asiatic Society of Bengal:—

No. 1. *Goolabee*, named from its rose-colour and considered the best.

No. 2. *Musooreea*, named from its colour, resembling that of *musoor-dal*, a kind of lentil, and regarded as of second quality.

No. 3. *Bhakra*, from its varied colours, 3rd in quality.

No. 4. *Teleeya*, resembling in colour the seed of the *telee*, 4th in quality.

[1] Kulu, its beauties, etc., p. 54.
[2] *Ibid.*, p. 92.
[3] *Edinb. Phil. Journ.*, Vol. II, p. 305 (1820).
[4] *Journ., As. Soc., Beng.*, Vol. XV, Proc., p. xv (1845).

No. 5. Impure, mixed with mica scales.

No. 6. Very impure, mixed with fibrolite.

Captain Sherwill mentions a belief that the rock, by permission of the gods, was considered to be for one day, and one day only in the year, corundum; during the remaining 364 days it is common rock and of no use; this was evidently the story of the clever owner of the quarry, who thereby avoided the otherwise inevitable pilfering. Mr. Mallet mentions that in 1872 it was considered necessary, before undertaking mining operations, to propitiate the guardian spirit of the mine by the preliminary sacrifice of a kid.

According to Mr. Mallet, who examined the deposit in 1872-73, the corundum rock occurs in a small hill between Pipra and Kadopani (sheet 18, Rewah Survey), and about a mile east of the Rehr river, the beds having an irregular strike about east and west.

The section across the hill from south to north is as follows:—

a. White quartz-schist.

b. Hornblende-rock passing into jade, a few yards thick.

c. White tremolitic quartz-schist breaking with a fibrous fracture.

d. White and green jade, including some purple corundum and containing euphyllite and schorl: *c* and *d* are about equal in thickness to *b.*

e. Bed of corundum several yards thick. It is a reddish, sometimes purple or grey, rock almost compact to finely-crystalline in texture, and containing emerald-green euphyllite and sometimes schorl and diaspore in seams.

f. Porphyritic gneiss with hornblende-rock. Junction not exposed.

Some of these beds, however, thin out rapidly, and at the west end of the hillock porphyritic gneiss and white quartz-schist are seen within ten yards of each other with corundum between.

The corundum bed in one place reaches 30 yards in thickness, the surface of the hill being covered with blocks, some of which are not less than two or three tons in weight, and the supply is practically inexhaustible. The merchants paid at the time of Mr. Mallet's visit (1872) at the rate of R2-8 for 7 maunds (of 40 seers), or about 18 shillings a ton for the mineral. The quarrymen were paid at the rate of one rupee per 15 pukka maunds; but the work was only carried on irregularly.[1]

According to Professor Judd, the Rewah purple corundum has a specific gravity varying from 3·84 to 3·88, the variation in density being due to mica and other secondary minerals. With it are associated, besides the minerals already mentioned, rutile and picotite (chrome-spinel).[2] The rutile was noticed by Mr. Mallet as minute crystals disseminated

[1] *Rec., Geol. Surv., Ind.,* Vol. V, p. 20 (1872), and Vol. VI, p. 43 (1873).

[2] *Min. Mag.,* Vol. XI, p. 58 (1895).

through the corundum rock, and as larger crystals in the seams with the euphyllite and tourmaline.

TRAVANCORE.

According to Dr. Balfour,[1] corundum in limestone from the Travancore State was exhibited at the Madras Exhibition.

Dr. W. King,[2] late Director of the Geological Survey of India, mentions the occurrence of red, blue and yellow sapphire in the garnetiferous sands of the Travancore coast; but the Travancore Government is unable at present to give any further information as to the occurrence of corundum within the limits of the State.

1 Selections from Records, Madras Government, Vol. XXXIX, p. 94 (1857).

2 General Sketch of the Geology of the Travancore State, *Rec., Geol. Surv., Ind.*, Vol. XV, p. 89 (1882).

V. USES OF CORUNDUM AND ITS PRECIOUS VARIETIES.

Although corundum is the richest ore of the metal aluminium, which has during the last few years been developed to such a very great extent, the crushed mineral is more valuable as an abrading agent than as a source of the metal aluminium, and this state of affairs will probably persist as long as there are supplies of the softer hydrated oxides, like bauxite, available for metallurgical purposes.

As already stated, corundum occurs either in the dull non-transparent form, in which case its hardness is the sole property which makes it economically valuable, or as the coloured, transparent varieties, which form the highly prized gem-stones ruby, sapphire, oriental topaz, etc. These two main forms of corundum—the "common" and the "precious," or, as Count de Bournon termed them, the "perfect" and the "imperfect" varieties—will be considered in proper order.

CORUNDUM AS AN ABRADING AGENT.

"Effective hardness."

Although it is the principal character upon which the value of a substance as an abrading agent depends, the mineralogical hardness of a mineral may not be directly proportional to its abrasive power. Emery, for instance, which contains a large percentage of minerals softer than corundum, sometimes exhibits a higher abrasive power, or *effective hardness*, than ordinary corundum on account of the numerous bits of non-cleavable sapphire which it contains, and which break with a conchoidal fracture into rough jagged grains, instead of into cleavage-fragments with plane or rounded surfaces, such as are obtained by the crushing of the common cleavable corundum.

The different varieties of corundum are thus found to vary amongst themselves in value as abrading agents. The sapphire, which shows scarcely a trace of the tendency to cleave along crystallographic planes, but breaks, like quartz, with a conchoidal fracture (*vide* p. 5), is far superior as an abrading agent to the commoner varieties of corundum, which are divided in several directions by the numerous parting planes that have destroyed the transparency of the mineral. In this particular case the loss of *effective hardness* is due not only to the tendency to so-called cleavage, but also to the development of secondary products along these planes (*vide ante* p. 6), which, during the crushing of the mineral, give rise to a large quantity of useless "flour," and result in the production of a grain deficient in cutting power.

With regard to the common impure form, emery, the abrasive power, or effective hardness, depends, not only on the particular state of the corundum which enters into its composition, but also on the proportion of the other softer minerals, like magnetite, with which, in common emery, it is always mixed. Common emery is sometimes found to be superior in

abrasive power to corundum on account of the minute sapphire crystals which occur in some specimens, like those of Naxos for instance.

Every lapidary in grinding down rocks must have noticed the rapidity with which the emery loses its abrasive power, and Dr. J. Lawrence Smith[1] has taken advantage of this fact in devising a scheme for determining the effective hardness of different samples of emery and other abrading agents, which is as follows:—Fragments are broken from the piece to be examined, and crushed in a diamond mortar with two or three blows of a hammer, then thrown into a sieve (of about 400 holes per square centimetre), the portion passing through being collected, whilst that remaining on the sieve is again placed in the mortar, two or three blows given, and again thrown into the sieve. The object of giving two or three blows at a time is to avoid crushing any of the emery to too fine a powder.

Determination of "Effective hardness."

When so pulverized, it is intimately mixed, and a weighed portion taken for the test. This is thrown little by little on a weighed piece of glass, and each portion ground against the glass by a flat piece of agate. This process is repeated until all the emery has been rubbed several times against the glass, which is then weighed, and the process repeated several times until the emery is reduced to an impalpable powder, and the glass ceases to lose weight. The total loss of weight in the glass serves as an index to determine the effective hardness of a sample of emery when compared with any other substance treated in a precisely similar manner. The best emery, when subjected to this process, will wear away about half its own weight of glass, whilst the sapphire under similar circumstances will wear away about four-fifths of its own weight.

Taking 100 as the numerical value of the effective hardness of the blue sapphire of Ceylon, and employing this as a standard, the effective hardness of the ruby would be represented by about 90; of common corundum from 77 to about 55, and of emery from 55 to 40 or even less.

Large lumps of emery are reduced for industrial application by first of all crushing in an ordinary stone-crusher to obtain lumps of about the size of hen's eggs, followed by further reduction in a stamping mill, or revolving grinding mill between cast-iron plates and chilled cast-iron rolls. The different grades are separated from one another by sieves, or by levigation in a row of upright cylinders connected in series by metal pipes at the top. A stream of water, mixed with emery from the mill, passes into the first cylinder, where the coarser grains are deposited, whilst the finer material is carried over into the next cylinder, where further emery is deposited, only the finest material reaching the last cylinder.

Preparation of emery.

[1] *Amer. Journ. Sci.*, 2nd ser., Vol. X, p. 362 (1850).

Grades of emery.

Emery powder is classified according to the number of holes in the sieve through which it passes, and the ordinary article of commerce generally varies from the "corn emery," which passes through a sieve of 16 holes to the inch, to "superfine flour," which passes through a No. 90 sieve. Finer sieves are, however, sometimes employed, and the very finest flour for special purposes is obtained by sifting through lawn sieves, whilst for lapidaries and opticians still finer material is obtained by washing in water. Different degrees of fineness are obtained by collecting the sediments which form after certain intervals of time, such as after 10 seconds, 30 seconds, 2 minutes, 10, 20 and 60 minutes. The finer material remains, of course, longer in suspension than the coarser, and to obtain more complete separation the sedimentation is sometimes retarded by adding gum-arabic to the water. The fine dust, which floats in the air and collects on the beams and shelves of the stamping room, is also used for lapidaries' work.

When, as in the Lucas Mill, Cullasaja, Massachusetts, the principal supply is corundum sand, the raw material is sent from the mines in sluice troughs to the mill, where it is treated with water in troughs, and fed to punched iron-screens with 7 or 8 holes to the linear inch. The "coarse" material remaining on the top of the sieve is re-ground between steel rolls and in the screw-mill, which breaks off the adhering chlorite, and is then re-washed. The material which passes through the sieves is separated into three sizes from No. 8 to No. 100 (the finest), dried and shipped as unfinished corundum in sacks to the refiner by whom it is sized more closely for the market in 8 or 10 grades as refined corundum. In the preliminary process of milling about two-thirds of the material brought to the mills being composed of hornblende, chlorite, etc., is rejected as waste. The average price of the crushed material is about 5 cents a pound.[1]

Uses of emery powder.

Emery powder is used in various ways as an abrading agent, the most common being those in which the material mixed with glue is used as a coating for paper, cloth and wood, all of which are used in various ways by smiths for polishing metal and other hard substances. An ingenious application of the cloth is the emery-tape machine, in which an endless band of emery cloth is driven with a high surface speed and so used for polishing articles of irregular shape. Other forms are emery cake in which suet and bee's wax are used to cement the abrading agent, Edward's patent razor-strop paper, which consists of finely powdered emery and glass mixed with paper pulp; and the corundum rubbers made in India either of lac and the powdered mineral or grindings from agates and other hard minerals which are cut with corundum.

Besides its use by the armourer, which was formerly a much more flourishing industry in India than now, emery, and the crushed forms of

[1] Mineral Resources of the United States, 1893, p. 677.

corundum generally, are used largely by the lapidary for cutting and polishing hard stones.

Indian lapidaries.

The Indian lapidary (*begri*) uses different kinds of discs (*sán*) for cutting precious stones. Corundum discs of different grades are used for the rough cutting of minerals softer than diamonds, whilst the polishing is done on discs of bell-metal, or pewter, according to the hardness of the stone, the abrading agent being the powder of the stone which is being cut.

Besides the ordinary *begri* or lapidary, there are men whose business it is to bore holes through precious stones, and they are known as *bidhiya*. The *bidhiya* squats on the ground with the stone to be pierced fixed on a three-legged stool in front of him, and proceeds to work with a steel *barma* (gimlet) worked with a *tasma* (leather strap) fixed to a *kamáni* (bow). Water is allowed to drop on to the stone into which the steel gimlet, armed with corundum-dust, gradually erodes a hole.

Corundum is also used by the *náginasaz*, a man who cuts up pieces of coloured glass for false jewellery, and by the *kataiya*, whose business it is to cut into smaller pieces the large masses of crystal imported by the jeweller. The *kataiya* cuts his rocks by means of a heavily loaded bow with wire working in powdered corundum and water.

Seal-engravers.

According to Mr. Archibald Constable, corundum is still used in Lucknow for engraving seals. At the end of steel spindles, of varying size according to the fineness of the work to be done, small discs of copper are fixed. The spindles are placed in an ordinary seal engraver's lathe, and the discs being anointed with corundum-powder and oil are made to revolve against the flat surface of the stone to be engraved, which can be manipulated as required. The same process is employed by the *muhar-band* (seal-engravers) of Kashmir.

The emery or corundum wheel.

Powdered or granulated emery or corundum is also cemented into compact masses by lac to make the ordinary corundum or *emery-wheel*.

The emery-wheel has been described as a rotatory file whose cutting points never grow dull. It is rapidly replacing the file for cutting down metal surfaces, and the grindstone for sharpening steel tools. The emery grains throughout the wheel retain their cutting power, so that it can be worked until quite 90 per cent. of its original weight has been worn off, whilst a file is useless before it has lost 5 per cent. of its weight. It has been estimated that to remove one pound weight of iron with a file costs 2*s*. 6*d*., whilst the same amount of work can be done by an emery-wheel in about one-eighth of the time and at one-seventh of the cost. Compared with grindstones in grinding tools, experiments by some English firms show that the cost of the emery-wheel is about one-fifth and the time only one-half of that required by the use of the old grindstone, and at the same time the danger of bursting during rapid revolution, which is such a common accident with the latter tool, has been practically abolished.

The corundum-*sane* or lapidaries' wheel, as used in India, is composed of about two-thirds of finely crushed corundum cemented with one-third of lac-resin. The powdered corundum is heated in an earthen vessel, and when sufficiently hot, the resin is added in successive portions, with constant stirring of the melting mass. The mixture is placed upon a slab of stone, kneaded, rolled and re-heated several times until the mass is perfectly homogeneous. It is then laid upon a stone table previously covered with fine corundum powder, and flattened into the form of a wheel by an iron rolling pin. The central hole is made by a heated metal rod, and the wheel finally polished with corundum on an iron plate. Different grades are made according to the work for which they are intended.

There are various types of this wheel patented in Europe and America, generally differing in the nature of the cement used for binding the emery granules into a compact mass. One of the oldest of the modern type of emery wheel is the "Sterne" wheel, which was the outcome of an improved process, patented by Messrs. Jacques and Fanshawe (since L. Sterne & Co) in 1862, for cementing emery by means of camplicon, or so-called oxidized linseed oil, mixed with shellac or asphalt and sulphur. In the "silicate" wheel the cementing material is silicate of soda. The base of the "vulcanite" or "black" wheel is india-rubber, whilst that of the "red" wheel is shellac, and of the "union" wheel oxychloride of magnesium. The "tanite" wheel, which has a great reputation in America, has some form of a so-called solution of leather for its cement; but the process of manufacture is kept secret.

Various grades of emery are of course used in the manufacture of emery wheels depending on the nature of the work for which they are intended.

With the increasing practice of using the emery-wheel the number of its applications is becoming rapidly extended. Besides its use in sharpening ordinary tools, and especially for sharpening machine saws, emery-wheels are used for grinding steel-keys into shape, for trueing slide-bars and crank-pins of locomotives after case-hardening; for trueing case-hardened and chilled rolls; for pully-grinding and for numerous other uses in the mechanical workshop.

Emery stones.

Emery stones are made by mixing emery with about half its weight of Stourbridge loam with sufficient water to make a stiff paste, which is forced into moulds, and when thoroughly dry, raised to a bright red heat in a muffle furnace. Stones are also made by pressing moistened emery flour into moulds under great pressure and heating the brick to a white heat. The emery stone patented by Mr. H. Barclay in August 1842 was designed originally by him for making artificial teeth and gums of a hard porcelain, which was found to be too hard for the ordinary quartzose grindstone to cut rapidly.

Medical use of corundum.

Like many minerals, common corundum is used in India for *medicinal purposes*. The *hakims* (native doctors) of the Punjab use calcined corundum as a cooling medicine in fevers

(dose about 16 grains). They also apply it to wounds to stop bleeding (see also ruby and sapphire).

Prices of corundum and emery.

The prices of common corundum and emery are of course subject to many local but limited variations. Owing to a monopoly, the Greek emery rose from £7 to £30 a ton in 1847, but on the letting out of further lands by the Turkish Government, new mines were opened and the price in the London market went down to £15 and £10 a ton.

According to Mr. Andrews, Principal of the Mayo School of Art, Lahore, corundum is sold wholesale in lump at the rate of three seers (6 lbs.) per rupee and is retailed in Delhi at the rate of 8 or 9 annas a seer (2 lbs.).

In 1881, 500 short tons of corundum were raised in the United States, and the annual production remained about stationary till 1889, when 2,245 tons were raised. In 1890 the quantity amounted to 1,970 tons; in 1891 2,247 tons, whilst in 1892 the production of corundum in the United States was reduced to 1,771 short tons. In 1893 the production was 1,713 short tons, a decrease of 58 tons; but the value declined from 181,300 to 142,325 dollars, a decrease of 20 per cent. The principal supplies are obtained from Rabun County, Georgia; Macon and Jackson counties, North Carolina; West Chester County, New York, and Hampden County, Massachusetts. The mining of corundum in Chester County, Pennsylvania, ceased in 1893.[1]

CORUNDUM AS A GEM-STONE.

Besides the uses to which the common form of corundum is, on account of its exceptional hardness, applied in the arts, the precious (*perfect*, pp. 3 and 52) varieties, ruby and sapphire, are esteemed as the most valuable of all gem-stones, the former being even more valued than diamonds of the same size. The high value placed on these precious stones is partly of course due to their natural beauty; but there is no doubt that their value is partly owing to the survival of ancient beliefs in the marvellous medicinal and magical powers of these gems; for when actual mineralogical tests, such as those of crystalline form, pleochroism, hardness, and specific gravity, cannot be made, even expert jewellers are often unable to distinguish the ruby from the red spinel, which is so abundantly extracted from the same limestone in Burma. On account of the semi-supernatural powers ascribed to gems in ancient times, the natural physical characters became greatly exaggerated, and thus we find it stated in the works of classic Hindu writers that the sapphire, when thrown into a hundred times its bulk of milk, colours the whole mass with its native blue,[2] whilst the *padmarága* (ruby) will turn the same quantity of milk into an entire sheet of red, will make the lotus bud to blossom,

[1] Mineral Resources of the United States, 1893, p. 674.

[2] *Maní-málá*, p. 439.

and after exposure to the rising sun will paint the whole house with crimson.[1] It is doubtless the unconfessed, and perhaps unconscious, survival in more sober form of such beliefs in their beauty and in their magical powers that preserves the high esteem in which the ruby and sapphire are still held as articles of personal jewellery.[2]

The Ruby.

The Hindu classic authors evidently classed spinels with rubies; but they distinguished the true ruby, *padmarága*, as a *vipra* (Brahmin), the highest of four castes of gems, the *kuruvinda* being classed as a *Kshatriya;* the *saugandhika* as a *Vaishya;* and the *mansa-khanda* as a *Shúdra.* The last three are probably varieties of magnesia-alumina spinel.

Like the *anthrax* of Theophrastus the *vipra* rubies were likened by the Hindu writers to a red-hot charcoal,[3] and whilst some of their properties were regarded as auspicious, others were of ill-omen. A *padmarága* of good colour and lustre was thought to bring wealth, success and long life, and many are the stories told in the *Puránas* and other classic writings of the Hindus of the fabulous prices paid for this gem-stone. But those which emit a two-fold shade (*dwi-chchháya*),[4] bring about the death of friends; those which bear a mark like a bird's foot (*virupa*) bring humiliation to their owner. A ruby with a flaw (*samveda*) renders its owner liable to blows from a weapon; those with gritty fragments (*karkara*) cause the death of friends and domestic animals; those which are milky in colour (*asovana*) are the source of many evils. A mark like a drop of honey (*kokila*) in a ruby makes the gem inimical to life, wealth and fame; a discoloured ruby (*jara*) causes loss of wealth, whilst one which looks like smoke (*dhumra*) renders the owner liable to lightning stroke.[5]

With the Hindu classic writers special names were given to rubies according to their colour, of which as many as sixteen shades were recognised. Those like the *bandhuka* flower (*Pentapetes phænicea*) were called *bandhujibi*, those resembling the *gunja* berry (*Abrus precatorius*) were called *simandika;* those like the cochineal, *indragopi;* those resembling the China rose, *odrapushpaka;* those like blood, *raktákhya;* those like the seed of the pomegranate, *kuttima;* those like the *kinsuka* flower, *parna;* those like vermilion, *simantaka* and *manirága;* those resembling the eye of the Greek partridge, *chakaráksha*, and those like the red lotus, *kokanada.*[6] Many of these and the other described colours are probably of spinels and garnets.

[1] *Mani-málá*, pp. 205—207.

[2] These stories are only a degree more extravagant than many occurring in the European classics. See King, "Precious Stones and Gems" (1865), pp. 150, 424.

[3] It is believed in India that rubies grow in the heads of serpents, who use them to illumine the place where they search for food, thus attracting insects by the light (*Mani-málá*, p. 238).

[4] The true ruby is dichroic; but the word *dwichchháya* probably refers to irregularity of colouring rather than to the polychroism recognised by the mineralogists in such coloured doubly refracting crystals.

[5] *Mani-málá*, pp. 209—213.

[6] *Mani-málá*, pp. 195—197.

The Sapphire.

Sapphires were, like rubies, divided into four castes by ancient Hindu writers, *Bráhman, Kshatriya, Vaishya* and *Shúdra.* They were judged according to their weight, depth of colour, coolness and transparency. To the apparent *coldness* of the sapphire when touched, the ancients, both eastern and western, ascribed to this gem the power of extinguishing fire, and of curing fever, inflammation and evil passions. For the last reason it is stated to be used in the episcopal ring of office from the Middle Ages down to the present day [King (1865), p. 201].

The sapphire through which any lustrous substance, such as crystal or silver, can be seen was called *pársvavartí;* such sapphires were supposed to bring fame. As in the ruby, certain defects in the sapphire were regarded as evil omens. Sapphires with a mica-like sheen on the surface were known as *avraka,* and were supposed to bring loss of wealth and life. Those with fracture-flaws (*trása*) render one liable to bites; those variegated in colour (*citraka*) cause loss of family dignity; those containing dirt (*mrídgarva*) produce skin-diseases; those which are rough (*raukshya*) bring banishment to the wearer.

Cutting of Gem-stones.

Although the superior workmanship of European experts has materially decreased the trade of the Indian lapidary, the industry still survives in places. According to Mr. W. Hoey, who made a comprehensive report on the trade and manufactures of Northern India in 1880, rubies and sapphires are cut by Indian lapidaries after three principal styles or *bandish*:—(1) *taura,* that is, level above and below, with bevelled edges, (2) *mathaila,* level below and round upper surface, (3) *tilakridar,* level below and cut in facets above. The *begri* (lapidary) who cuts a ruby or sapphire is paid according to the *bandish* as follows:—(1) *taura,* one rupee per *ratí,*[1] (2) *mathaila* and (3) *tilakridar,* eight annas per *rati.* Higher rates are, however, paid to ensure good workmanship on stones of exceptional value. If a ruby be more than one rati in weight, it is called *mánik,* if less, *chuni.* The *taríf* (formula expressing quality) of a good ruby is *surkh be aib kabutar ki ánkh* (faultless, blood-red like the pigeon's eye) variatim, *atlas ka tukra* (like satin).

The following defects are distinguished by modern Hindustani jewellers in the ruby:—*chir* (fissures), *dudhuk* (milky), *abruk* (micaceous scales), *dábhá* (absence of "water"), *binausi, párek* (fissures and milky

[1] The rati is a small, red berry, also known as *ghungchi* or *gunja*—the seed of *Abrus precatorius.* The weight is about 1·843 to 1·85 grains. Weighment of the seed gave General Cunningham and Mr. Laidlay 1·823 and 1·825 grains. Mr. Blackie has obtained, by weighment of seeds in the Bellary District, an average weight of 2·142 grains (*Proc. As. Soc., Beng.*, 1887, p. 222); the seeds in the south are, however, larger. The use of the *rati* as a weight corresponds to the use of the *carat* in Europe, and of the barley-grain in England long ago for both weights and measures.

imperfections combined), *jutla* (yellowish hue together with other defects), *jávlá* (rose-red or black colour with other defects).[1]

Prices of cut rubies.

According to Chapuzeaux (1665),[2] a ruby weighing one *rati* (see p. 59) was worth in India 20 old *Pagodes*, each *Pagode* being about ten shillings of English money.

A ruby of	2 ratis	was valued at		100	Pagodes.
,,	3 ,,	,,	,,	250	,,
,,	4 ,,	,,	,,	500	,,
,,	5 ,,	,,	,,	900	,,
,,	6 ,,	,,	,,	1,500	,,
,,	7 ,,	,,	,,	2,300	,,
,,	12 ,,	,,	,,	12,000	,,

Tavernier[3] figures and gives an account of the large rubies seen by him in the possession of the King of Persia, the King of Bijapur and the Great Mogul; but it is impossible to be sure now how many of the ruby-coloured stones mentioned by the older writers were really the red variety of "perfect" corundum.

Although possibly not equal to the oriental stories, records show that the prices paid for the ruby in ancient times in Europe were very high. According to Benvenuto Cellini (quoted by Streeter) in his time (sixteenth century), a perfect ruby of a carat weight cost 800 *ecus d'or*, whilst a diamond of like weight cost only 100. At the present time, according to Streeter, rubies under half a carat weight, if English cut, cost from £4 to £10 per carat, and if Indian cut, £1 to £4.

According to Emanuel, rubies of good colour, well spread and proportioned, fetch the following prices (in 1865):—

	£		£
One carat weight	14	to	20
One and a half carats	25	,,	35
Two carats	70	,,	80
Three carats	200	,,	250
Four carats	400	,,	450

Stones of greater weight than four carats are of such exceptional occurrence that they command fancy prices. The two most important rubies ever known in Europe were brought from Burma in 1875, one weighing 37 and the other $47\frac{1}{16}$ carats. When re-cut, the stones weighed $32\frac{5}{16}$ carats and $38\frac{9}{16}$ carats respectively. The smaller stone, it is said, brought £10,000 and the larger one £20,000. Two such rubies are not to be found in any European regalia (Streeter, 1884).

Many of the famous rubies known in Europe can be recognised to be of Indian origin on account of the way in which they are pierced through the middle. About the most notable of these is the huge specimen appro-

[1] *Mani-málá*, pp. 908, 909.

[2] Translation of Abstract of *Histoire des Joyaux*. *Phil. Trans.*, Vol. II (1667), pp. 429—436.

[3] Ball's Translation of Tavernier's Travels, Vol. II (1889), p. 471.

priately placed in front of the crown of the Empress of India. This ruby is said to have been given to Edward the Black Prince by Don Pedro, King of Castile, after the battle of Najara, near Vittoria, in 1367, and was worn in the helmet of Henry V at the battle of Agincourt.

Watch jewels.

Besides the use of rubies and sapphires for purely ornamental purposes, small specimens of these gem-stones are used for bearings in watches. G. F. Kunz states that about 1,200,000 watches with jewelled works are manufactured annually in the United States, requiring about 12,000,000 jewels, of which 5,000,000 are ruby and sapphire, the remainder being garnets.

Cut sapphires.

Three classes of sapphire are recognised by Hindustani jewellers:—*subj-pun nílá* (with a tinge of green), *lál-pun nílá* (with a tinge of red) and deep-blue. The defects are classified as in the case of the ruby.[1] A good sapphire is spoken of as *alsi ka phúl* (flower of the linseed plant). Besides being cut in the styles described for the ruby (p. 59), sapphires are made up as ear-rings, as *goshwára*, the shape of an elongated pigeon's egg, and *badámcha*, or almond-shape.[2]

English-cut sapphires under one carat in weight vary in price from £4 to £12. According to Emanuel, the value of the sapphire does not, like that of the ruby, increase so enormously in proportion to its size. A fine, perfect, evenly-coloured, spread sapphire, weighing one carat, of a deep, rich, blue colour by night as well as by day, is worth £20, whilst a sapphire, equally fine, of 100 carats, would not be worth more than £2,000 to £3,000. A ruby of the same size and perfection would be the most valuable gem in existence, surpassing even that of the finest diamond.[3]

Amongst well known sapphires of Indian origin Streeter mentions one which was brought to England in 1856. It weighed 225 carats and was Indian-cut, but was improved by re-cutting and is now the finest sapphire of its size in Europe, being estimated to be worth from £7,000 to £8,000.[4]

[1] *Mani-málá*, p. 915.
[2] Hoey, Trades and Manufactures in Northern India (1880), p. 119.
[3] Diamonds and Precious Stones (1865), p. 112.
[4] Precious Stones, 4th Ed. (1884), p. 171.

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VII.—VERNACULAR GLOSSARY.

S refers to Sanscrit words used in the classical writings in connection with rubies and sapphires. They are all found in the extracts given in the *Maní-málá*. *H* refers to words now used in Hindustani and of various derivations:—

Ai-ái (Burmese), rubies in their rough state.
Aiye le (Burmese), rubies of poor water.
Aiye soye (Burmese), variegated rubies.
Aiyode (Burmese), dark-coloured rubies.
Anide (Burmese), rose-coloured rubies.
Anigyi (Burmese), dark rose-red rubies.
Asobhana (S), milky rubies.
Avraka (S), sapphires with a mica-like sheen.
Badámcha (H), almond-shaped, the common shape for cutting sapphires.
Bandish (H), the style of gem-cutting.
Bandhujíbí (S), rubies coloured like *bándhuká* flower (*Pentapetes phœnicea*).
Barma (H), a gimlet worked with a bow for boring stones.
Begri (H), lapidary.
Bhakra (H), name applied to the variegated form of Rewah corundum.
Bidhiyá (H), a man who bores holes through precious stones.
Binausi (H), fissured and milky rubies.
Budmiyá (Burmese), ruby.
Chakarákasha (S), [rubies] coloured like the eye of the Greek partridge.
Chír (H), fissure.
Chitraka (S), variegated [sapphires].
Choni (Burmese), ruby.
Chúni (H), term applied to rubies weighing less than one *rati*.
Dábhá (H), absence of water.
Dhuduk (H), milky, term applied to rubies, etc.
Dhúmra (H), smoky [rubies].
Dwi-chchháya (H), rubies of two shades.
Goolabee (H), name applied to the rose-coloured variety of the Rewah corundum.
Goshwára (H), gems shaped like an elongated pigeon's egg.
Hmyaudwins (Burmese), "water-mines", open cuttings made in the hill-wash for recovering rubies.
Indragopi (S), rubies coloured like the cochineal.
Jávlá (H), rose-red and black rubies with other defects.
Jutlá (H), rubies with a yellowish hue.
Kamání (H), a bow used for working a gimlet in gem-stone boring.
Karkara (S), a crushed ruby.
Kataiyá (H), a man who cuts the rough stones into smaller pieces for the *begri*.
Kenu sá (Burmese), rubies in their rough state.
Khar (H), precious stones in the rough.
Kokila (S), rubies with honey-coloured spots.
Kokiláksha (S), rubies coloured like the eye of a *kokila* (*Cuculus Indicus*).
Korund (H), corundum.
Korundikal (Tamil), corundum stone.
Kshatriya (S), the second caste, applied in the same sense to gems.
Kuruvinda (S), a ruby of the second (*Kshatriya*) caste.
Kuttima (S), [rubies] coloured like the pomegranate seed.

Lál-pun níla, (H), sapphires with a tinge of red.
Lálri (H), an inferior ruby.
Loodwins (Burmese), tunnels cut in the ruby-bearing limestone.
Manak (Persian), ruby.
Mánik (H), term applied to rubies weighing over one *rati*.
Mánsa-khanda (S), a ruby of the fourth (*Shudra*) caste.
Mathaila (H), gems cut with a flat under surface and rounded above.
Maushynrut (Khasi), corundum.
Menyu guni khanu yanghe (Burmese), deep-red rubies.
Mridgarva (S), sapphires with earthy inclusions.
Muhar-band (H), seal-engraver.
Mussoorea (H), corundum coloured like *mussoor dal*, a lentil (Rewah).
Naginasaz (H), a man who cuts coloured glass for false jewellery (*nag*, false gem).
Nílá (H), [blue] sapphire.
Noh (Burmese), milky rubies.
Odrapushpaka (S), rubies with a rose-red tint.
Okthapaya (Burmese), very pale yellow and green corundum.
Padmarága (S), a ruby of the highest (*Vipra*) caste.
Pániyáng (Burmese), rose-red rubies.
Parek (H), fissured, milky rubies.
Parna (S), rubies coloured like the *kinsuka* flower.
Pársvavartí (S), term applied to transparent sapphire.
Raktákhya (S), blood-coloured rubies.
Rati (H), a small berry used as a weight for precious stones (see p. 59).
Samada (Gujeráti), corundum.
Sambheda (S), a ruby with a flaw.
Sane (H), the corundum-wheel.
Sangtarásh (Persian), stone-cutter.
Saugandhika (S), a ruby of the third (*Vaishya*) caste.
Shúdra (S), the fourth or lowest caste of Hindus, applied also to gems.
Sikhandika (S), rubies resembling the *gunjá* berry in colour.
Símantaka (S), vermilion-coloured rubies.
Subj-pun níla (H), sapphires with a tinge of green.
Táblá (Burmese), cut rubies.
Tanjín (Burmese), polished rubies.
Taríf (H), formula expressing the quality of a gem.
Tasma (H), a leather strap used with a bow (*kamání*).
Taura (H), gems cut flat above and below with bevelled edges.
Teleeya (H), corundum like the *telee* seed (Rewah).
Tilakridar (H), gems with a large flat face below and cut with small facets above.
Trása (S), sapphires with flaws.
Twinlones (Burmese), round pits made in the ruby-bearing alluvia.
Twinzein (Burmese), green corundum.
Vaishya (S), the third caste of Hindús, applied also to gems.
Vipra (S), Brahman, the highest of the four castes of gems.
Yakút (Arabic), ruby.

INDEX TO LOCALITIES.

Names of districts are printed in italics, those of provinces, presidencies and native states in Capitals. The co-rdinates given with names of taluks are those of the head-quarte town in each case.

	Latitude.		Longitude.		Page.
	°	′	°	′	
S					
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T					
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Tarvalli, „	12	14	76	26	46.
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U					
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